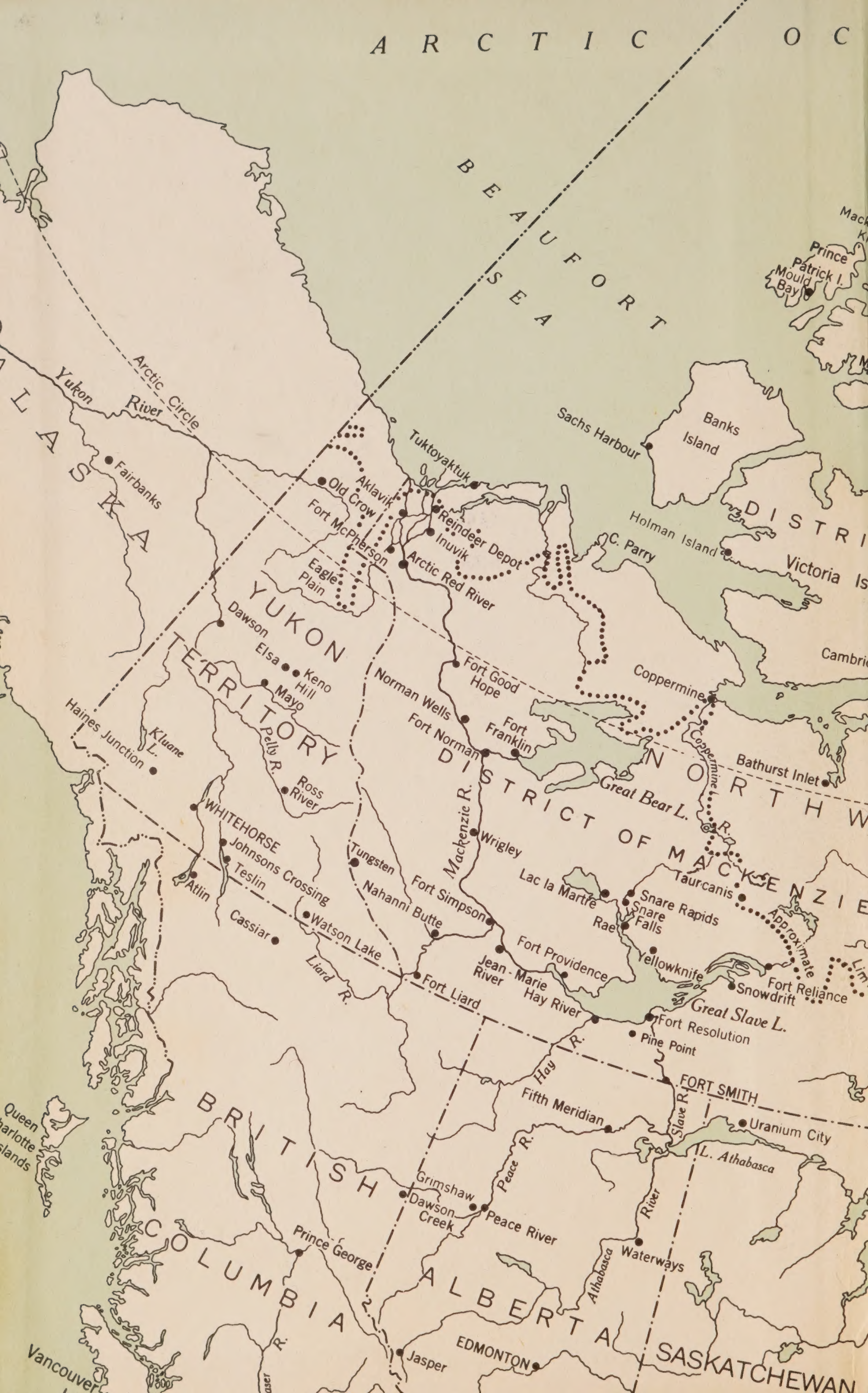
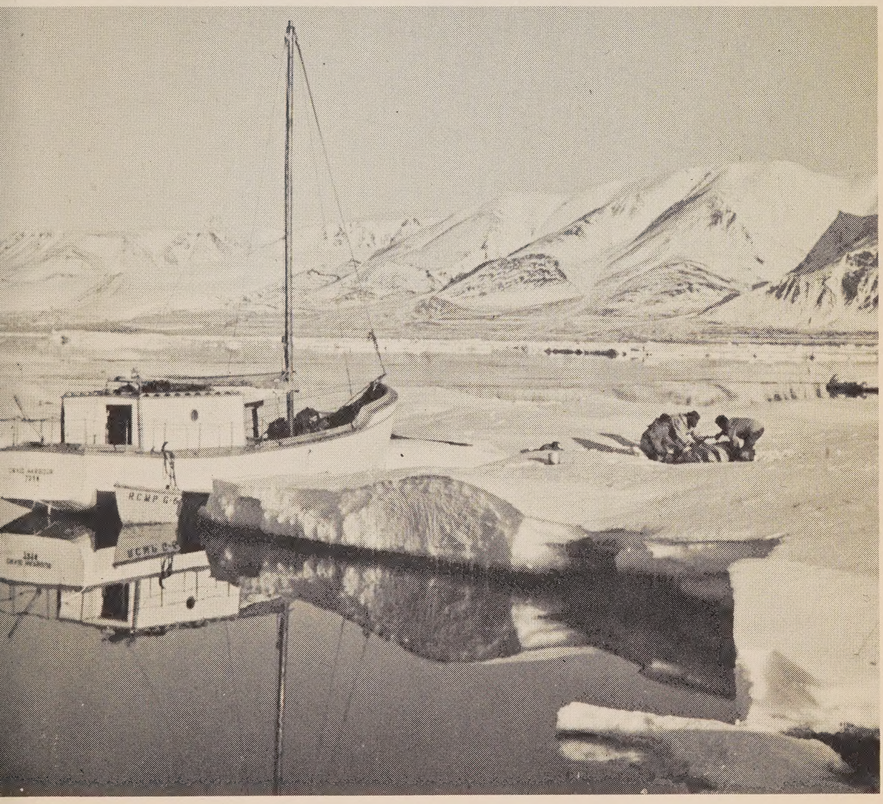
THE UNBELIEVABLE LAND


ARCTIC OC
BEAUFORT SEA
ALASKA
Yukon River
Arctic Circle
Fairbanks
Mackenzie King I.
Prince Patrick I.
Mould Bay
Banks Island
Sachs Harbour
Tuktoyaktuk
Aklavik
Old Crow
Fort McPherson
Reindeer Depot
Inuvik
Arctic Red River
Eagle Plain
Holman Island
C. Parry
DISTRICT
Victoria Is
Cambridge
YUKON TERRITORY
Dawson
Elsa
Keno Hill
Mayo
Kluane L.
Haines Junction
Pelly R.
Ross River
WHITEHORSE
Johnsons Crossing
Teslin
Atlin
Cassiar
Watson Lake
Liard R.
Fort Good Hope
Norman Wells
Fort Norman
Fort Franklin
Coppermine
Coppermine R.
Bathurst Inlet
NORTHW
DISTRICT OF MACKENZIE
Great Bear L.
Mackenzie R.
Wrigley
Tungsten
Nahanni Butte
Fort Simpson
Lac la Martre
Taurcanis
Snare Rapids
Snare Falls
Rae
Yellowknife
Approximate
Fort Providence
Jean-Marie River
Hay River
Fort Liard
Fort Reliance
Snowdrift
Great Slave L.
Fort Resolution
Pine Point
Hay R.
FORT SMITH
Fifth Meridian
Slave R.
Uranium City
L. Athabasca
Queen Charlotte Islands
BRITISH COLUMBIA
Grimshaw
Dawson Creek
Peace R.
Peace River
Prince George
River
Waterways
Athabasca
ALBERTA
Jasper
EDMONTON
SASKATCHEWAN
Vancouver
Fraser R.


GREENLAND
Alert
Ellesmere Island
Axel Heiberg I.
Eureka
Isachsen
Ellef Ringnes I.
ELIZABETH ISLANDS
Grise Fiord
Bathurst I.
Cornwallis I.
Resolute
Devon Island
BAFFIN BAY
Somerset I.
Prince of Wales I.
Arctic Bay
Pond Inlet
Clyde
Baffin Island
Spence Bay
Igloolik
Hall Lake
Prince Charles I.
Broughton Island
Pangnirtung
Gjoa Haven
Pelly Bay
Repulse Bay
Arctic Circle
TERRITORIES
DISTRICT OF KEEWATIN
Southampton Island
Coral Harbour
Cape Dorset
Baker Lake
Chesterfield Inlet
Rankin Inlet
Whale Cove
Eskimo Point
Notre-Dame-d'Ivugivic
Sugluk
Wakeham Bay
Resolution I.
Notre-Dame-de-Koartac
Port Burwell
Povungnituk
HUDSON BAY
Fort Chimo
Port Harrison
Churchill
Belcher Islands
Schefferville
Nelson R.
Winisk
Ft. George R.

The Land



Still Life at Craig Harbour, Ellesmere Island.

Ship time at Pangnirtung, Baffin Island. Everyone pitches in to help unload the barges from the *C. D. Howe*.

A glacier moves and twists at varying speeds as it flows towards sea level.

We speak of "ice ages" as things of the past. This edge of the Barnes Ice Cap in northern Baffin Island, with its mix of dirt and rock, remains to tell the story, as do others in the eastern Arctic.

Polar bear on a pinnacle—Cape Chase on the Raanes
Peninsula, Ellesmere Island.

In June, 1962, the land at Lake Hazen in northern Ellesmere Island had shed its snow, but ice still gripped the lake. The "Operation Hazen" Base Camp, described in Chapter 25, lies slightly beyond the first point of land in the foreground.

7

The earth breaks into curious blisters or blobs in the Mackenzie delta. These blisters are called "pingos" and rise as high as 150 feet. Dr. Mackay writes of them in Chapter 13.

(See next page.) Stranded ice near Cape Dorset.

9

10

In 1845, Sir John Franklin and one hundred and twenty eight officers and men sailed from England to seek a Northwest Passage through the Arctic Archipelago. They spent the winter of 1845-46 on Beechey Island at the mouth of Wellington Channel, between Cornwallis Island and Devon Island. Here three men who died were buried in a bleak, rockstrewn land. Then Franklin's ships, the *Erebus* and the *Terror*, sailed away. Neither they, nor any of Franklin's men, were ever seen again. The fourth grave is that of one of the members of the many expeditions that set out to seek Franklin and his men.

11

12

This is not a picture of a North African desert that slipped in by mistake—it is badland weathering on Prince Patrick Island, some 700 miles north of the Arctic Circle.

What does the Arctic look like? There are a hundred answers. In Flagler Bay, Ellesmere Island, a tent and limestone cliffs catch the rays of the setting sun.

13 The way sea meets sky in the Arctic—Cape Dorset, Baffin Island.

In arctic lowlands, specially in the Mackenzie River delta, frost patterns the ground into all manner of circles, polygons and squares. Here, on Prince Patrick Island, the sea has flooded them, making the land look bomb-beaten. Dr. Mackay describes patterned ground in Chapter 13.

Rocks on the Fosheim Peninsula of Ellesmere Island shatter into strange shapes under the extremes of arctic heat and cold.

Man alone amid the sweep of sea, mountain and sky—
Broughton Island.

The Unbelievable Land

Published by the Queen's Printer for the Department of Northern Affairs and National Resources and the Northern Service of the Canadian Broadcasting Corporation.

Contents

Foreword

ne hundred years ago there were many who said that a little ettlement near Lake Winnipeg would never grow into anything iore than a trading post. Later still, men denied that the Prairies ould ever be opened up for grain-growing. The same kind of eople have doubted that there is a future for the one-third or iereabouts of Canada that lies north of the 60th parallel.

'or those who have seen the Northland there can be no pessiiism. The vitality and freshness of the country, the integrity nd humanity of its people proclaim its destiny.

t is known that the Canadian Shield and Arctic Lowlands enlose a great treasure of nature's hidden riches. This is the lure iat will bring ever growing numbers to the North. In search of ealth they will find character also and from the combination f these elements will come the fulfilment of Canada's promise.

few years ago my wife and I had the privilege of travelling ver six thousand miles in the northern regions that are the nknown part of our country. It was a happy and most memorable xperience. The wonders of the land must be seen to be believed nd appreciated.

eturning to the thin southern strip of Canada where most of s live, we were sadly aware of the fact that our country cannot chieve its full destiny so long as its unique but distant parts emain unknown and undeveloped. Having seen them ourselves, e were prouder than ever of the land and its people, and rateful beyond measure to the pioneers who have opened up ie North and are still doing so.

'he following pages give some idea of the magnitude of our eritage and the achievements of the men and women who have een our stewards. On its face, this book contains a series of talks

originally broadcast over the Canadian Broadcasting Corporation's Northern Service by experts on the Arctic. Published together, they form an unusually authoritative and interesting narrative of what the Arctic is and means, and of what is being done to tame it. The book brings great credit both to those who study the North and to those who live there.

The authors are all eminent in their field. They are mostly the silent civil servant or the dedicated university teacher or scientist. They are doing great things for Canada, quietly, whether high or low in office, whether navigators or scientists, teachers or engineers or road makers. This book is a tribute to these people and, indeed, to all their colleagues everywhere working however obscurely for the Arctic.

It is also a tribute to the ordinary people who live in the North: Eskimos, Indians and Whites. The experts make us realize the value and importance of the human element. Without it, the ground must lie fallow. Fortunately, we have in Canada men and women in the tradition of their forefathers. They derive satisfaction in creative work. They are attached to the Northland by the joy that comes from learning to master a challenging environment.

The presence of such people, whose inward character reflects self-discipline and whose outward attitudes show concern for their neighbours, is a great strength for Canada as a whole. The debt owed to them is no local charge. It is one that the entire country is proud to honour, for it is through them and others like them that there can be "a true North, strong and free".

January 15th, 1964.

The Unbelievable Land

I. NORMAN SMITH

Introduction

When a book is graced with a Foreword by the Governor General and a Conclusion by R. Gordon Robertson the editor might properly be anxious that the heart of the book be worthy.

Happy and appreciative as we all are about the Foreword and Conclusion, I think there need be no anxiety about the inner content. Authority and quality are here: twenty nine experts on the Arctic speaking to us not off the top of their heads but from their life's core. Here are scientists, philosophers, explorers, botanists, geologists, archaeologists—and people whose study is people.

Whose happy thought caught all these nomadic and adventurous characters between the covers of one book? Not mine. A bit more than a year ago Maja van Steensel-James, producer of the Northern Service of the Canadian Broadcasting Corporation, mused on the number and variety of experts she had occasionally met or heard in the North. They were plying their erudite mysteries among the natives and amid the vastness in virtual aloneness and, to them, happy anonymity. "I should get these men to do a series of broadcasts for the Northern Service", thought she. With help from the Arctic Institute of North America, Maja van Steensel-James cast her net from Yukon to Labrador and over a six-month period wheedled, begged and flirted the best minds on the Arctic into making a unique symposium on their work. Three of them are holders of the Massey Medal of the Royal Canadian Geographical Society "for outstanding personal achievement" in the North.

"It was fun", she says; "particularly nailing them down for a moment. These men don't stay put. One, due on the air in ten days, was off digging a Viking site somewhere in Newfoundland! Another elusive species forgot me while looking for plankton in the Arctic Ocean!" It probably *was* fun, but it was also on her

part a fine piece of editorial production and a valuable contribution to the public's knowledge of the Arctic.

It was the latter aspect that more recently caught the eye of Jim Lotz in the Northern Co-ordination and Research Centre of the Department of Northern Affairs and National Resources. He pressed the idea that the talks should be given the permanency of book form, and with Maja van Steensel-James' grinning support, duly won that Department's approval.

It is thus late in the story that I came in. They believed they needed an editor who could prepare the book so the ordinary layman would be interested and understand. Perhaps my curiosity about the Arctic qualified me for such a role. Three years as a member of the Northwest Territories Council have not made me an old arctic hand, and certainly not an expert, but they have touched me with something of the North's enchantment and a desire to spread the word.

My task was to reduce the over-all length, to minimize duplication, to ask some questions and, perhaps, to clarify and simplify. But not to over-simplify. There's some hard thinking and hard reading ahead but the North rewards most those who give it most. We refused to squander the minds and lives of our twenty-nine experts by reducing them to pale talk for pale people. It has been a stimulating and most happy experience. Working with the authors has revealed again the old truth that the really able people are easy to get along with. I am grateful, too, for the friendly help of many in Northern Affairs, and of the Queen's Printer and his people, and for the gifted guidance of Paul Arthur in the book's design.

I have sought to knit the experts' pieces together by the device of a short editor's note before each. These notes are set in italic, like the type of this paragraph.

For surely obvious reasons I make no attempt to assess these articles. Let me say simply that they excite me. I can hear the clamour of the murres as suddenly they make a grand exodus to head south from their nesting cliffs on an arctic island. I see a herd of caribou swimming a river. I cherish Dr. Jenness saying quietly, with his mischievous smile, that as to the Eskimos having short arms and smaller nostrils "I am unable to answer these troublesome questions"—and he knowing more about the Eskimos than the Eskimos! I stand in awe before the advances of science

in probing the environment of land, sea, ice and air—and one man talking of boring to the centre of the earth! I honor the attitude of Dr. McLaren (reflected in most of the articles) wherein he says "unravelling these interactions will be *the task and the pleasure* of arctic marine biologists for years to come". And I am moved by the deep humanitarianism in which they all approach their work, a work Gordon Robertson well describes as being "to enlarge the spirit of man, to enable him to bring out his best qualities, to give him the opportunity to reach, power to grasp, purpose to hold, and promise to build."

I hope the reader will share these excitements.

Nobody claims this book has covered all of the progress being made in the Arctic. Even in the phases touched upon one is impressed that the experts speak only of a work begun. But one hopes the book has reflected enough of that beginning to give meaning to Mr. Robertson's assertion that how we solve the problems of our North will influence greatly "the role the future has in store for Canada as a whole". If the book does that, then I think it will have paid some of its debt to its authors, and to the people who live in the North. "The debt owed to them", as the Governor General has so gracefully written, "is one that the entire country is proud to honour".

I.N.S.

The following essays, originally written as radio talks, were broadcast over the Northern Service of the Canadian Broadcasting Corporation under the title "As a Matter of Fact" and were produced by Mrs. Maja van Steensel-James in co-operation with the Montreal office of the Arctic Institute of North America.

DR. TREVOR LLOYD

1: The Land and the People

The term "human geography" opens all the windows. To take the first general look at the Arctic is a professor of human geography. The Northwest Territories and Yukon, embracing the Arctic, make up more than one third the area of all Canada – with only 37,000 people! What problems – but what opportunities and challenges!

If we are to study the development of the Canadian Arctic, it is well to look first at its geography, including its human geography.

Northern Canada is not all a single unit, with the same conditions everywhere. Not everyone realizes that the Mackenzie Valley stretching to almost 70° north latitude, has rather warm summers even if it does have severe winters, and that this part of the North has trees running all the way down to the Arctic Sea. On the other hand, in the eastern part of northern Canada, there are no trees, for there the true Arctic extends southward, even well down into Labrador.

So here we have one very important distinction between two parts of northern Canada: the true Arctic – the area north of the tree line, the land of the Eskimos; and the Subarctic – the area south of it, where there are trees – the land of the Indians and an increasing number of white settlers.

There is another and very important distinction, and this, though it concerns rocks, is really an economic one. A large part of northern Canada is what we familiarly call the "Canadian" or "Precambrian Shield". This is an area of immensely ancient rock that includes many minerals such as uranium, gold, radium,

silver, iron ore and others. This Shield is the mining area of northern Canada. To the west of it, and also to the north of it, there are newer rocks which are also potentially valuable, for they contain coal and oil.

The physical basis of the North I have been touching on includes not only the land itself but also the climate, that is the air above it; and the vegetation represented in part by the forest, or by the arctic prairies or tundra. This provides the background against which life is carried on.

Now, there is another kind of very important distinction between one part of the far North and another. This is in the possibility of reaching the area. It is very simple to get into some parts of northern Canada and extraordinarily difficult to get into others.

Let us start with land transportation. The Mackenzie Valley can now be reached by road, and is soon to be reached also by railroad. It is reasonably accessible, it is not cut off by high mountains, and is not isolated by seas. On the other hand, most of the eastern part of the Arctic cannot be reached over land.

When we consider shipping, we are faced with quite another situation. One cannot, obviously, get into the Mackenzie Valley by sea, except at the very far North, and this means going the long way around by the Aleutians and northern Alaska. The eastern Arctic, on the other hand, can be reached by sea quite readily – from the Atlantic, through Hudson Strait, from Churchill on Hudson Bay, and the northern islands from Davis Strait and Baffin Bay. This is the route of the Northwest Passage of old. Unfortunately, as we all know, ice is the hazard here. The shipping season is short throughout the eastern Arctic, and is cut down to a couple of months or less in the very far North. Such difficulty in reaching the Arctic is bound to have profound effects on any attempt to develop the resources there, whether minerals or others.

Finally, the age of flying has meant more to the Arctic than anywhere else on earth. The air makes it possible for us to travel over land or sea, over ice or mountains, irrespective of surface features. It is the airplane that has made life in far northern Canada possible today.

Some airplanes can land on ice, some on open water. Some can come down on a field or a small bush lake, others need large

and rather expensive airfields and radio facilities. But such is their versatility that it is possible for the city dweller of today to travel throughout the Arctic without any of the skills or equipment of the traditional explorer. All he needs is a flight bag!

Those who have studied northern areas in other parts of the world sometimes chide us in Canada, saying that we have not developed our north country as rapidly as have some others theirs. This subject has interested me for many years. I have made some study of Alaska, lived for a while in Greenland, have made a number of visits to northernmost Scandinavia, and have been a couple of times in the Soviet Union, though not as yet to its arctic areas. The conclusion that I've come to is this: We *have been* slow in developing our North – we were even negligent in the 1920's and the 1930's, when some other countries were very active.

But we have special difficulties that do not apply quite so much to the other northern lands. North Norway, for example is not arctic; it is at the most subarctic. You can buy a steamship ticket to travel around the North Cape of Norway on any day in the year, and that is in 70° north latitude – which is about the same latitude as the northernmost point of Alaska – which you certainly can't get around in a steamship, except in the summertime, and not always then. West Greenland, where the Danes have brought about such remarkable educational, economic and social development, is also specially favoured. In the southwest, it also is an area open to navigation throughout the year and it has a relatively mild climate even in the north. Even our friends across the North Pole in the Soviet Union, although they have a well deserved reputation for being experts in the Arctic, don't have as difficult an arctic area as we do. They don't have the maze of arctic islands that we have between the open sea and the mainland, which make sea transportation so very difficult. And the mighty northward flowing rivers of Siberia provide excellent transportation routes from the southern cities to the arctic coast.

Yet, I suppose we have been slow – and until recently unenterprising. But we have some advantages because of this! One of them is that we can learn from the experience of people in the other northern lands. Technology we can sometimes learn for example, from Alaska; in cultural and educational matters, such

as radio-broadcasting, school systems and social services, we can learn from Greenland; studying northern Scandinavia, we can benefit from the way the Lapps, the Norwegians, the Finns and the Swedes have all co-operated together in developing that area; and from the Soviet Union, we can learn many things, one being that the North is an integral part of the country as a whole; it is not a rather odd, remote and distinct region. One learns when talking to the Russians that they look upon their Northland as being not radically different from any other part of the country. The young men and women go there as school teachers, as scientists. Industrial workers go there, cities are built there pretty much as in the rest of the country, and one, Norilsk, has a population of more than 100,000 people – whereas the entire Canadian Northwest Territories contains only 22,000 people. The people of the U.S.S.R. are past the great days of exploration, they have overcome the old senseless fear of the far North. They now feel at home there and can, I think, show us in Canada much that could help in our own northern development.

I am sure all of us contributing to this book will agree that our future in the North requires firstly that we learn everything we possibly can about it. This means more scientific research and more scientists to do it. Secondly, we must encourage the younger people to go there and we must train them to be qualified in the skills that are needed there. Thirdly, we must see to it that those very able and interesting people, the Eskimos – who after all, lived there successfully for several thousand years before the white man even, so to speak, discovered it – are able to develop to the maximum that they can, and are given as much responsibility as possible in their own northern land. And finally, government and industry must somehow see to it that the necessary capital and other resources are made available to bring about the speedy development of this vast land. The North is something of which all Canadians should be proud. Those who live in the South should be grateful to all those who work there and should provide the funds, the technical aid and the encouragement they need.

DR. TREVOR LLOYD, *Chairman, Department of Geography, McGill University, Montreal. Born London, England, 1906. University of Bristol, B.A. 1929. Clark University, Ph.D. 1940. University of Bristol, D. Sc. 1949. Dartmouth College, Hanover, New Hampshire 1942-44, 1948-59. Canadian Consul, Greenland, 1944-45. Travelled to Churchill, 1934, Mackenzie Valley, 1942, Eastern Arctic, 1943, also widely in Europe, Lapland, Soviet Union. Fellow, Arctic Institute of North America.*

2: The Canadian Eskimo

"I have stalked the wild caribou with Eskimos," says Dr. Jenness, quietly. He has indeed; has shared their igloos, loved their hardihood and their lusty humor. Let this eminent authority on Canadian Eskimos introduce them to our minds – and hearts.

Fifty or sixty centuries ago, about the time when a few wise men in the eastern Mediterranean were inventing the art of writing to preserve the memory of things past, and the inhabitants of Egypt began to immortalize their illustrious dead by raising above them those majestic pyramids that draw so many tourists to the Nile today, in a far distant corner of the world a tiny fragment of the human race – the Eskimos – wandered along the shores and over the barren wastes of Canada's Arctic, seeking a peaceful home where they could live their alloted span and unobtrusively pass on the torch of life to their children.

The world forgetting, by the world forgot – as the poet says – they clung to that remote region through 4,000 and perhaps even 6,000 years, despite the harshness of the climate, the darkness and the cold of the long, blizzardy winters, and the ever-present danger of death from freezing or starvation. No other race, white, yellow or black, has ever wrestled with the polar region as they did and survived. No other people has ever settled there for more than a few days or weeks without constant assistance and support from the milder and richer world to the south.

How was it, we wonder, that only the Eskimos succeeded in overcoming the arctic environment? What advantages did they

possess over other races? What qualities, physical or mental, that other people lacked? Had nature perhaps endowed them with certain peculiar traits that helped them in their struggle?

With some qualities, we know, nature did not endow them, although she bestowed them on other living things that dwell in the Arctic. She did not shield them from the bitter cold by depositing an abnormally thick layer of fat under their skins, as she did on the seals and the polar bears. She did not protect their bodies with a dense warm coat of hair or fur such as she wraps around the caribou and the fox. The Eskimo does, or did, wear a coat of fur, but it was an ersatz one that he stole from those animals, and from the seal and the bear. He himself is more hairless than a white man, and seldom grows even a thin beard to protect – or endanger – his chin. He cannot store up fat and hibernate like the bear and the marmot, much as a few natives today might wish to. The majority really prefer the winter season to the summer, for grown-ups as well as children love to romp in the snow.

It is true the Eskimos are a little different from other people, even though they are sometimes mistaken for Chinese. The long arms of a Negro reach to his knees, and occasionally lower. A white man's rarely touch his knees, and an Eskimo's extend only about half-way down his thigh. His hands and feet, too, are smaller than ours, as you quickly discover if you try to put on his gloves or sealskin slippers. Is this because in a very cold climate it is easier for the heart to pump warm blood into short limbs than into long ones? Then again, the nose cavities through which an Eskimo breathes are smaller than the cavities in other races. Is that to protect his lungs from freezing when the wind is howling, and the thermometer registers fifty degrees below zero fahrenheit? We feel as perplexed as a traveller in Africa who asked his guide, "Does the giraffe strip the leaves from tall trees because his neck is so long? Or has his neck become phenomenally long from the habit of stripping tall trees?"

I am unable to answer these troublesome questions. I do know, however, that although the Eskimo's hands and feet will freeze almost as quickly as my own, he is a tougher individual than I am and will struggle on without a moan. I know, too, that he has an unusually sensitive funny-bone, and will plod doggedly along

a seemingly endless trail until he drops from sheer exhaustion, provided I keep tickling that funny-bone with remarks that he finds amusing. He is a loyal and cheerful companion on a hard journey, and if his eyes should slant a little more than mine, if his cheek-bones show up more prominently, why should I care? The companion I need is a man who will march steadily beside me when the going is rough and a blizzard is lashing our faces. And the Eskimo is just such a man.

It has taken more than toughness, however, and a lusty sense of humour, to win a livelihood and raise up families in the Arctic, generation after generation, without any help from the outside world. It has required great adaptability and inventiveness to cope with the strange and exceedingly difficult environment, where no trees grow because the ground is forever frozen below the top few inches; where berries seldom ripen on the rare bushes because the summer is too short; where all birds except three species, one of them the useless raven, flee the region for eight months of every year; and where the sea hides nearly as many animals as roam the land. How could man feed and clothe his family in such an environment? What sort of house could he build that would shelter them during the long, dark nights of winter? How could he heat his house? How illuminate it during the weeks, in some places months, when the sun does not rise above the horizon?

We know from travellers' descriptions how the Eskimos contrived to do all these things. Some of us have seen them with our own eyes. I have stalked the wild caribou with Eskimos who were armed only with bows and arrows: I have watched them practice those clever tricks to which every primitive hunter must resort if his family is not to die of starvation. In northern Alaska I have helped Eskimos build small cabins from driftwood which the Mackenzie River carries down to the Arctic Ocean, and to insulate those crude dwellings with clods of earth; and farther east, where driftwood is lacking, I have learned from them to erect a dome-shaped house of snow – the igloo – which melts away under the rays of the spring sun, and even in mid-winter drips water on your head if too many warm-blooded visitors crowd into your home. In my own snow-hut I could fry bacon, and boil rice and oatmeal, over a kerosene-burning primus stove; but the only food many of my Eskimo friends had ever tasted was

the meat of the caribou, the seal and other wild game that they killed, and the fish they caught in the lakes and in the sea. Sometimes, through lack of fuel, they ate their food raw, but generally they cooked it in stone pots heated by stone lamps that burned the animal's fat or blubber. A trained economist would have observed how they practised in their kitchen the same division of labour as we do. It was the men who manufactured the pots and the lamps, but only the women knew how to use them – or so at least they claimed. A ten-year-old girl could trim a lamp to perfection, but any man who dared to disturb its wick invariably smoked up the whole dwelling.

As in the kitchen, so too in the art of tailoring, women displayed a marked superiority over men – as, of course, they do in every civilized society. Of all the world's people outside Europe and part of Asia, only the inventive Eskimos ever made separate coats and trousers tailored to fit their wearers. The ten-year-old girl who had learned to keep the lamp smokeless, and to preserve all the flavour of caribou tongues by boiling them with the tips upward, could cut out and stitch a perfectly fitting suit of caribou fur artistically adorned with inset patterns; but the man who attempted to make or to mend his own clothes looked like a hobo. We need not wonder, then, that before the white man entered the Arctic, no one ever heard of an Eskimo youth or an Eskimo maid reaching the age of eighteen unmarried. Each needed the other. Might we not bring about this same happy condition in southern Canada if we sternly abolished all men tailors and all men cooks?

In many other ways the Eskimos have revealed more than usual adaptability and ingenuity. It was from them that we Europeans learned to speed over the frozen sea with dog sleds and to capture great whales and walruses with hand-harpoons. The light foldboats, in which some of our holiday seekers explore the inland waters of Europe and a few of our North American rivers, are but imperfect copies of the Eskimo's *kayak,* the skin-covered boat from which he harpooned the seals in the ocean, and speared the caribou as they swam the rivers and the lakes during their spring and autumn migrations.

Nevertheless, for arctic living the Eskimos needed more than short limbs and narrow noses, adaptability and resourcefulness.

Their stern environment, where throughout nearly half the year cold and darkness confined them for sixteen and eighteen hours each day to one roomed dwellings, which every neighbour entered at will, and into which every stranger or chance visitor squeezed for shelter and rest; an environment whose innumerable dangers, seen and unforeseen, limited their average span of life to only twenty years, forcing them to cling to one another for safety, to share every hardship of fishing and the chase, and to hold all food in common; that environment imposed upon them a deep social consciousness, strong social bonds which man elsewhere has generally worn very loosely, but which the ants, the bees, cattle and many other forms of life hold inescapably tight. The Eskimos had to abrogate all privacy; to submerge, yet at the same time to preserve, their separate individualities; and to acquire an endurance of each other's company, and a tolerance of each other's idiosyncracies, far beyond the capacity of most Europeans.

We of old world descent, who through our superior knowledge of nature's forces have long held the rest of the world at our mercy – we incline to be mavericks, weaker than other peoples in the social consciousness that holds human communities together. But now that this atomic age, with its fantastic powers of destruction, links together all mankind in a common fate, we must either develop a more profound sense of our obligations towards our fellow-men than even the Eskimos possessed, or prepare to follow the dinosaur and the mammoth into total oblivion.

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GRAHAM ROWLEY

3: But Change Confronts the Eskimo

There are only 60,000 Eskimos in the whole world, of which 12,000 are in Canada. If "civilization" is to overwhelm them can it first learn their friendly ways?

The Eskimos are often described as a little-known race. Nothing could be further from the truth. Few travellers to the North have been able to resist writing about such a delightful people. The result is that there is no difficulty in finding material on the Eskimos. The problems lie in trying to keep up with the flood of literature, in separating truth from fiction, and in keeping a sense of proportion. It is easy to forget that there are only 60,000 Eskimos in the whole world and that only a fifth of them live in Canada. The world population of Eskimos is less than the population of, say, Brantford, and Ottawa has more than twenty times as many people as there are Eskimos in Canada. The number of people in the world increases each day by nearly twice the number of Eskimos alive. There are in fact so few Eskimos that there are scarcely enough to go round the number of people wanting to write about them, and any incident involving Eskimos is eagerly seized upon by hungry authors.

Though there are so few Eskimos, they cover an enormous area and both archaeology and the accounts of early explorers show that they once extended even further. They live in four different countries – Russia, the United States, Canada, and Denmark; they live in both Asia and America, and on both sides of the Iron Curtain. In Russia there are only about 1,500 Eskimos; in

Alaska between 15,000 and 20,000; in Canada around 12,000; and in Greenland nearly 30,000. Before the discovery of Alaska, more Eskimos probably lived there than in all the rest of the world put together, but the early contacts with civilization were disastrous, and the population is still much less than it was then. In Greenland, on the other hand there has been a steady increase over the past 150 years and now about half the Eskimos live there. The greatest concentration of Eskimos is no longer in the west, but in the east.

Let us consider what is meant by the term "Eskimo". It is derived from an Algonquin Indian word meaning "a man who eats raw meat" but you have to do more than eat raw meat to be considered an Eskimo. There are several ways of classifying mankind. The commonest ways are to group people by their physical type, by the language they speak, or by how they live and think. These are usually rather imprecise groupings. For instance, the English have hair and eyes of many different colours; they are certainly not the only people who speak English, and even without the Common Market they lead much the same sort of life, wear the same sort of clothes, and play the same sort of games as most of the people of western Europe. The Eskimos on the other hand are a very distinct people. They have an easily recognized physical type, they speak a language spoken by nobody else, and they have evolved their own special way of life, different from that of any other people, enabling them to live and be happy under the most extreme conditions.

The most remarkable thing about the Eskimo language is its uniformity over a large area. An Eskimo from Greenland can make himself understood with not very much difficulty all across northern Canada and Alaska as far west as the mouth of the Yukon River. South of the Yukon and in Siberia, the dialects are very different and our Greenlander would not at first recognize the language as Eskimo. The Yukon forms the boundary between these two divisions of the Eskimo language, sometimes called Inupik to the east and north and Yupik to the south and west. Aleut, the language spoken in the Aleutian Islands, is now known to be an Eskimo language and forms a third division, but it is so different from the others that it used to be considered as completely separate.

Let's now pass on to how the Eskimos live, or what anthropologists call the Eskimo culture. It is the arctic climate that has fashioned the Eskimo culture. Most Canadian Eskimos live in the Arctic and they are what we consider to be typically Eskimo. Except in the summer they are an ice-hunting people, basing their lives on hunting sea mammals through the ice at their breathing holes, from the ice at the floe-edge, or on the ice when the seals lie enjoying the spring sunshine. These sea mammals provide the Eskimos with meat for food, oil for heat and light, and skins for clothing, tents and cord. Cut into long strips the skins serve in place of rope. In the winter the Eskimos use dogs and sledges and, since nature provides little else in the way of building materials, they live in snow houses. In the short summer sea mammals are again hunted but from *kayaks* and *umiaks,* or nowadays often from canoes and whaleboats, and the Eskimos live in tents of skin or canvas. At this time, too, fish are speared in the rivers and, more important, caribou are hunted, partly for their meat but particularly for their skins which provide splendid winter clothing. Nothing made in civilization can compare with the warmth, lightness, or comfort of the caribou skin clothing. There are no large Eskimo settlements because the game resources can nowhere support a large population, and Eskimo villages rarely exceed a hundred people.

This typical arctic form of Eskimo life is necessarily modified where conditions are not typically arctic and, of course, whereever the Eskimos work for wages. The most northern Eskimos, the Thule Eskimos of Greenland, have so little summer that the summer phase is unimportant. In fact, the *kayak,* the fish spear, and the bow and arrow, all of which are associated with summer hunting, had been forgotten by the Thule Eskimos of north Greenland when they were discovered by Ross in 1818. They were reintroduced by immigrant Eskimos from Baffin Island in the 1860's. Among the southern Eskimos on the other hand, the winter phase becomes less important. In the subarctic culture of southern Greenland, southwest Alaska and the Aleutians, there can be little hunting on the ice, but the use of *kayaks* and *umiaks* is much more developed.

Nowadays, modern civilization is changing the way that many Eskimos live, and each year fewer follow these traditional pat-

terns. Some people welcome these changes, others deplore them, but there can be only admiration for a race that has succeeded in wresting a living against such odds.

We can learn a lot from the Eskimos, not only from the way they have managed to survive in the North but also from the way they live together without friction. A people that depended on hunting could find little security in accumulating capital. What they killed would not keep for long, and possessions hampered mobility. For them security lay in helping one another, in working together and sharing what they killed. There was nothing to be gained by losing one's temper with one's own team or with the elements. This may be what has made the Eskimos such a friendly, charming, and cheerful people.

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4: The Eskimo Language - Must it Die?

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It is a very old language and it threatens to disappear because of disuse and because of the confusing variety of dialects – and because "The South" is moving north.

The part of Canada which extends north of the Arctic Circle is inhabited almost exclusively by Eskimo-speaking tribes, related to the Eskimo Aleut family of languages. The latter stretches from the Aleutian Islands and the extreme northeastern tip of Siberia, across the State of Alaska and northern Canada to the eastern coast of Greenland, which is a Danish province.

It comprises two main groups: the Aleut languages and the Eskimo languages, the alternate heading to this article being of the latter group.

The Aleut group of languages resembles the Eskimo group only slightly. It is scattered along the chain of the Aleutian Islands and divided into a number of different dialects. We will not enlarge upon this group since it is located outside Canada.

The Eskimo group comprises two subgroups, the Yupik and the Inupik. These names are derived from the word "man" in each of the language groups, respectively *yiut* and *inuit;* the suffix- *pik* meaning language-group.

The Yupik group is scattered through the Yukon, northern British Columbia, Alaska and the eastern shores of Siberia, but is not found on the Alaskan islands where Aleutian is spoken.

Inasmuch as they are divided geographically, the dialects of Yupik differ considerably more than those of Inupik.

Inupik is the language-group which includes the greatest part of Canadian Eskimo. It is spoken in five regions and divided into as many dialects. The first region is outside Canada, in Greenland, where the greatest number of Eskimo-speaking people live; there are around 30,000. These people have developed literature in their language but no longer refer to themselves as Eskimos, preferring the name Greenlanders.

The grammar of Greenlandic Eskimo is similar to that of Labrador Eskimo but the sounds and vocabulary are different.

The second region is Labrador and northern Quebec including the Belcher Islands in Hudson Bay. These dialects recently have begun to undergo a very strong cultural influence from the Whites. The structure of their language has begun to give away.

In the third or Central region, which includes most of the Baffin Island, Coppermine and Archipelago Eskimos, one can find many ancient characteristics of the language and some basic differences from the dialects of other regions.

In the fourth region, that of the Caribou or Barren Land Eskimos around Ennadai Lake, the people live mostly off the caribou herds. It is the only inland Eskimo tribe and due to their isolation they have developed many peculiarities of language.

The fifth group, the Western Eskimos, mainly inhabit the Mackenzie region and the northern part of Alaska.

Now a few words about the structure of the Eskimo language. The latter is an independent family of languages in itself, as far as connection with Asia or any other language of the world is concerned. Its main feature is that it incorporates many units of meaning in one word by the use of affixes, suffixes or infixes. To those unfamiliar with these terms a brief illustration can be found in one of the longer compound words in English, such as "antidisestablishmentarianism." In the latter *anti-* and *dis-* are prefixes, *-ment-* and *-ism* suffixes and *-arian-* an affix. Infixes are like affixes but can be placed in many more positions; strictly speaking they do not exist in English. Let us take an Eskimo word, like a verb, which is quite easy to distinguish in French or in English from a noun. In Eskimo it consists of a root, which constitutes only a small part of a word, and a series of syllables

which connote the difference of tense, mood, doubt, or any other shade of meaning you wish to give. The verb in Eskimo is surely central, but one cannot say whether it is a verb or a noun unless you see what follows in the word itself. It is like a fine piece of architecture which expresses by itself very subtle shades of meaning. The English or the French language cannot accomplish this without using many words or sentences.

Let us see how the Eskimo language works. According to Father Thibert, the author of a dictionary and many texts in Eskimo, it is through the system of infixes that you build your sentences in Eskimo. As a matter of fact a word can be a sentence and a sentence a word. Let us take as an example the idea or root of walking. I say the root *pishuk*, but I don't know whether it is "I walk", "he walks", "I will walk". The only definite idea it contains is walk. Now I say *pisukpuq*—he walks, *-puq* means 'he" and present indicative. When I say *pisuk-alayuq* I have added something in the middle of the word and I mean "he walks quicker," *-ala-* meaning quicker. Now, *pisu-inapuq,* "all he does is walking *-ina* meaning something like "all he does is-", and so on. The secret of the Eskimo language resides in this internal change.

What of the future of the Eskimo language? It is extremely difficult to predict anything within a fair range of accuracy for the traditional factors, as well as the Eskimos themselves, are undergoing the radical changes of our atomic age. Nevertheless, one can infer two main, interdependent, factors, that would seem to be essential if the Eskimo language is to survive. The first is the unification of the many dialects we have now in the North. This could come about through their merging together and that may be too long a process under the present circumstances; or through the acceptance of a standard written and spoken dialect, which will become a language. Will the Eskimos find enough intellectual and economic solidity to meet the challenge of Western civilization and assert themselves in front of other ethnic groups as a minority within Canada?

The other factor is the will of the Eskimo people to endure and to preserve ethnic characteristics, again as a minority. With the help of a unified language, maybe along the lines of Greenlandic, they conceivably could develop and strengthen a feeling of

ethnic and cultural difference from the rest of Canada. But I insist it would have to be a unified Eskimo language if it would breed and feed the feelings of the distinct and original people of the North.

It seems to me that the Eskimos themselves must decide these matters. All we can do now is help the Eskimos understand themselves, express themselves, and not impose our views on an altogether different ethnic group. Let us give them a chance and they will, in time, produce a definite answer.

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DR. J. S. TENER

5: The Animals That are There

The grizzlies don't hibernate they just "go into a torpid state from which they periodically recover". Like people? When muskoxen are attacked by wolves they quickly form a tight circle and with their curved horns as bayonets stand defiant as did the old British squares! Dr. Tener names twenty different arctic animals and writes of them as friends.

In spite of its harshness, the arctic region of Canada is the home of several kinds of land mammals. Those mammals range in size from the small arctic mouse (called the lemming) to the large forms such as the polar bear, caribou and the muskox. All of them have solved the problem of arctic living in one way or another.

Two bears live in the Canadian North.

The barren ground grizzly is found on the arctic mainland and is a somewhat smaller version of its close relatives in the mountains of the western provinces. The barren ground grizzly is not a numerous animal. In winter it avoids the extremes of weather by denning for about five months, after putting on a good layer of fat to tide itself over until spring. Like other grizzlies the barren ground bear is omnivorous, eating roots, berries, grasses as well as ground squirrels and such carrion as it may find. Grizzlies don't hibernate in the true sense of the word, but go into a torpid state from which they may periodically recover during the winter.

The second bear of Canada's arctic regions is the polar bear. Most of the life of this bear is spent away from land on the sea

ice or in the water itself. Distribution of this species is centred around arctic bodies of water which for most of the year are frozen or on which float large pans of ice; these support seal populations, the principal item of food of the polar bear.

Usually in October, the female polar bears, and some males, seek den-sites along sea coasts where snowbanks are deep enough. The females give birth to their young in the dens about mid-December after carrying young for about eight months. Emergence from the den is usually in mid-March and the cubs stay with the female for about two years. During the denning period the bears are in a torpid state but are not hibernating. They may awake occasionally and may even leave the den for short periods. Polar bears are hunted extensively by Eskimos, particularly in the eastern Arctic, in the waters surrounding Baffin and Southampton Islands. Bears provide food for sled dogs and skins for local use or for sale to visitors from the south.

The only true hibernator of the tundra regions is the ground squirrel, or *siksik,* which is found in the same general area as the grizzly, the arctic mainland. For about eight months of the year this squirrel is in hibernation in a burrow. Hibernation is a remarkable internal mechanism which permits the animal to live at a very low body temperature, often near freezing point. A low breathing rate, once every two or three minutes, conserves energy and heat during a period of food scarcity and low environmental temperature.

Lemmings are found throughout arctic Canada and as far north as northern Ellesmere Island. Unlike ground squirrels, lemmings are active the year round. Their body insulation or fur is inadequate for protection against arctic winter weather so they obtain shelter in tunnels and nests in the snow at ground level. Lemmings periodically undergo great changes in numbers. Every three or four years the animals are literally underfoot everywhere. With the melting of snow in the spring, evidence of their extensive tunnels and nests is almost overwhelming. During periods of such abundance, lemmings are food for many predators including birds such as snowy owls and jaegers, and mammals such as arctic foxes and wolves.

After reaching high population densities lemmings in one winter virtually disappear, or crash, as biologists say. Biologists as yet

do not have a precise explanation for the sudden, drastic reduction in lemming numbers.

Tales of suicidal drowning reported in northern European lemmings have not been observed in North America and, indeed, if the European situation is examined closely, a more rational explanation is apparent for large movements of the animals which result in drownings. With high population densities, lemmings are crowded and face competition from their fellows for food and space. The movements of lemmings across the countryside and into bodies of water are believed to reflect the escape of the animals from their crowded habitat, or homes, in search of better areas in which to live.

The fluctuations in numbers of lemmings are indirectly very important to Eskimos who trap arctic foxes for a living, because the principal item of diet of these foxes is lemmings. With increasing numbers of lemmings, foxes increase and hence more are available for trapping. When lemmings disappear over winter, foxes are forced to search for other, less available food, which is so scarce that fox survival is drastically reduced. Arctic foxes therefore fluctuate markedly in numbers every three or four years, affecting the economy of Eskimo trappers.

Arctic foxes are small creatures, weighing seven to eight pounds. They are present throughout arctic Canada and often are found on the sea ice out of sight of land. During the short summer months they wear a brown-grey coat but this is replaced in winter with the beautiful white coat which is so much in demand by the fur industry.

Over most of the Arctic, the wolf is the largest land carnivore. The exception is the barren-ground grizzly whose range, as I have mentioned, is virtually confined to the mainland. The arctic wolf is very much like the timber wolf except that it is usually white. It preys on caribou wherever that animal is found, and also feeds on such muskoxen as it can kill. Smaller animals like the lemming, arctic hare and birds also form part of its diet. Most wolves are under 100 pounds in weight although some may exceed that figure. Wolves generally form strong family groups and arctic wolves are no exception.

They usually mate for life. Young are born in June in dens excavated in sandy soils or in other sites where protection can

be given to the female and her pups. At about three to four months of age, the young wolves accompany the adults in their hunting forays, learning techniques from their parents. Contrary to popular belief, a wolf does not always hamstring a fleeing prey such as a caribou, but usually pulls the animal down by seizing the flank or throat. The old belief that wolves take only the weak or sick animal also appears to be untrue. It is often a matter of chance which prey animal is selected. If during a hunting trip, for example, a healthy caribou is sighted, that animal is the one the wolves will pursue. Hunting trips, by the way, often cover a large area, a nightly trip of twenty miles being not uncommon.

Wolves are an integral part of the animal life of the Canadian North and as long as they do not present a threat to the existence of other animals or interfere with man's activities unduly, they should remain to perpetuate their kind. Too many species of birds and mammals in this world have already been exterminated by man to permit another being pushed out of existence.

Another important mammal of the North is the arctic hare. It also is widely distributed, being found as far north as northern Ellesmere Island. A large adult hare weighs ten to twelve pounds but the average weight is somewhat less. During winter, arctic hares are white but in summer those in more southerly latitudes are brown in colour. It is interesting to note that hares on the northernmost islands such as those on the Queen Elizabeth group remain white the year round.

The hare is the prey of foxes and wolves and, on occasion, of the snowy owl. Eskimos also may hunt them for their soft white skins or for a change in diet.

In addition to the caribou (to be discussed in the next article) the Arctic harbours one other large cloven-hoofed mammal, the muskox. Muskoxen were introduced a number of years ago to Nunivak Island off the coast of Alaska, to Spitsbergen and to Norway, but the animal in its wild state is found only in Canada and Greenland. Latest available information indicates that Canada has between 9,000 and 10,000 muskoxen. The population has increased slowly since 1917, after fifty years of market hunting and killing for food by Indians, Eskimos, whalers and explorers. The species was fully protected that year and only extremely limited use has occurred since then.

Muskoxen at one time were found in Europe and Asia as well as North America, but became extinct in the Old World with the warming of the northern hemisphere after the last glaciation. Muskoxen appear to have been adapted to a cold climate for many thousands of years, as they still are today.

Superficially an adult bull muskox looks somewhat like a buffalo but is actually related to the sheep and goats of the world. The only living close relative is a wild cow-like animal of Tibet, the takin. An adult bull muskox reaches 900 to 1,000 pounds in weight and a cow some 300 pounds less. Weights of captive animals are greater by several hundred pounds. Both cows and bulls have a long outer coat of hair and a very soft, thick inner wool.

The calf muskox is born in late April or in May and, if a female, reaches maturity when three years of age. Cows produce a calf every two years but occasionally every year if food conditions are unusually good. Twins are rare in Canadian animals. The animals are nearly always found in herds. An unusual characteristic is the defence a herd will form when under attack. If approached by wolves, for example, grazing muskoxen quickly form a tight outward-facing group, more or less circular, with the calves and yearlings crowded against the flanks of the adults. Because bulls and cows possess sharp curved horns, such a defence formation is quite effective against wolves, although not perfect.

Muskoxen eat many different kinds of plants, but willows, grasses and sedges are the staples of their diet.

Except in a few favourable areas muskox herds are rather small in size, ranging between two and fifty-two with most under twenty-five. Herds also are usually widely scattered.

Muskoxen, like high arctic caribou and arctic hares, do not migrate to southern areas to avoid winter, nor do they hibernate. They not only must contend with very low temperatures but also with winter darkness, which may last four months or more at high latitudes. The problem of obtaining sufficient food in a dark, snow-covered and cold environment is not easily solved. What little light is provided by stars, the moon and from the noon-hour glow on the horizon is used to advantage in the search for food. Muskox eyes, like those of all ungulates, can adapt to darkness remarkably well, and helped by the memory of well-

vegetated areas grazed in summer, permit the animals to find adequate forage. One point not generally realized is that the Arctic is a desert, much of it receiving less than eight inches of precipitation a year and some of it less than four. That means snow cover is generally shallow, making search for vegetation easier.

The Canadian North has a fascinating and useful complement of land mammals. To sum up: there are the masked shrew, arctic shrew, tundra shrew, pigmy shrew, polar bear (perhaps 10,000), grizzly bear, short tail weasel, wolverine, red and white fox, grey wolf, brown and collared lemming, meadow vole, tundra red-back, tundra and yellow-cheeked vole, arctic hare, muskox (perhaps 10,000), barren ground caribou (perhaps 250,000).

Knowledge gained from studying these mammals is used in the drafting of legislation to insure wise harvesting and the perpetuation of species facing possible danger of extinction. Some of the knowledge also gives scientists a better insight into our Arctic and how man may best live there and draw upon the resources available. With man's penetration of the Arctic, northern land mammals have much to offer him there for his aesthetic and practical enjoyment.

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6: . . . Specially the Caribou

The restless tide-like journeyings of the caribou remain a boon to the natives and one of Nature's great wonders which man is trying not to destroy.

One of the most important natural resources of the North is the caribou. It has always been an important source of food and clothing to northern Indians. Eskimos are primarily a coastal people and obtain most of their livelihood from the resources of the sea such as seals, walrus and whales. However, the fall caribou hunt is also important to them as a source of winter clothing and a change of diet. Much of the permanently frozen and rocky arctic terrain is unsuitable for livestock and so the caribou remains an important resource adapted to the country.

The caribou of northern Canada is known by a number of names: caribou, *tuktu, ethan,* or simply – the deer. The most commonly used name – caribou, comes from the Micmac Indian name which means the shoveller, or the animal that paws through the snow for its food. The name of the English fur trade days – the deer – is an abbreviation of the word reindeer. That name is appropriate too because it is the American representative of the Old World reindeer.

Nowadays when we use the word reindeer we think only of the domesticated animal imported to America from Lapland or Siberia. However, there still are herds of wild reindeer in Norway, Finland and northern Russia. Those wild reindeer, which are ancestral to the smaller domestic reindeer, look and act a great deal like our native caribou. Indeed in northern Siberia there are herds of many thousand wild reindeer which still carry out

annual migrations from the forests to the tundra in the same way as do our barren-ground caribou.

There are three races of caribou found in Canada. The large dark woodland caribou occurs in the coniferous forest belt from Newfoundland to the Yukon: the smaller barren-ground caribou migrates between the tundra and the treeline belt: the smallest and palest form, the Peary caribou, is found on the islands of the Canadian Arctic Archipelago.

At one time caribou occurred in immense herds, so great that their numbers rivalled the antelope on the African veldt or the buffalo on the American prairies. Like those great natural resources they formed the cornerstone of the economy of the native inhabitants; in this case – the Eskimos and Athabascan Indians. The caribou provides a variety of basic requirements: excellent food, winter clothing that has not yet been surpassed for warmth and lightness, sinew for sewing, bone for needles, oil for fuel and light, and antlers for tools. It is interesting to recall that the same animal was found in western Europe 25,000 years ago, after the retreat of the last glaciation. The early Europeans left a clear record, in their cave drawings in Spain and France, of their utilization of the reindeer in the same manner of our northern Indians and Eskimos at the turn of the twentieth century.

One can well imagine the sight of natural bounty which greeted the first European explorers to northern Canada in the eighteenth and nineteenth centuries. Great herds of caribou which roamed the arctic tundra in summer and migrated in packed columns distances up to 800 miles to subarctic forests. The advent of Europeans upset the centuries-old balance which had existed between the caribou herds and their human predators. For the primitive weapons of the Eskimos and Indians scarcely gave them any advantage over their swift wide-ranging prey. The introduction of the fur trade indirectly tipped the balance against the caribou. The natives became trappers and the new occupation called for increased dog teams for winter travel. This led to larger caches of caribou meat to feed both trappers and dogs while on the trail. With these changes, was also introduced the tool necessary to facilitate the killing of caribou – the European's firearms. For the first time the Indian and Eskimo found himself able to kill, at will, the unwary caribou. The seemingly numberless caribou

herds began to melt away, until the present herds number only between 200,000 and 250,000.

One of the most interesting characteristics of the caribou is their migratory habit. They are great travellers, running with head and stubby tail held high and with a stiff-legged, springy stride that carries them tirelessly over many miles of springy tundra. In winter the widely splayed hooves act as snowshoes to easily cross the wind-packed snowdrifts. Most of the herds spend the winter months dispersed in the coniferous forests, where the shelter of the trees keeps the snow fluffy and permits easy pawing for their favourite lichens, or they may reach up for the tree lichens. Here they spend the lazy afternoons of late winter sunbathing on the frozen lakes. As spring approaches they follow the frozen water courses in loose files toward the distant treeline. The does (heavy with calf) have an extra urge to hurry to the tundra-clad hills to bear their young. The stags dawdle behind along the way. During the summer months they traverse the trackless tundra, browsing on the tender new growth of heaths, sedges, grasses and mushrooms. They must often seek the windblown hilltops or lakes to obtain some relief from the scourge of black flies and mosquitoes.

In late summer the bands of does, yearlings and new fawns check their drifting and retrace their steps towards the treeline where they are rejoined by the bachelor groups of stags. The rut occurs in October during the last spell of fine weather of "Indian Summer".

With the shortening autumn days, the early frosts which have blackened the tender green foliage, and the first blizzards, the caribou herds once again mass and commence their march towards winter quarters. This time they follow the deeply worn trails along the eskers and swim across the rivers and lakes in massed columns. The packed bobbing antlers give an observer the impression of a regiment of cavalry with lances, while the clicking of the foot bones suggests the clinking of armor.

It appears many conditions combine to cause the caribou to migrate. Factors such as seasonal food requirements, isolated terrain for the birth of fawns, soft, fluffy snow, strong winds, insect pests and probably many others affect the caribou movements. It appears that it is in the make-up of the animal to be a gregari-

ous nomad and to shun any particular base. Their home is the trackless northern wilderness of forest and tundra.

Some believe that the caribou is doomed like the buffalo to be forced to give up its territory in the face of advancing civilization. However, whereas the buffalo's role in the natural scheme of things was taken by the white-faced Hereford on the western prairies, there is no domestic animal better suited to utilize the lichen-forests and tundras than the caribou. With wise management it can continue to offer bounty "on the hoof" to northern Canadians for years to come.

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L. M. TUCK

7: Birds in the Arctic

Eighty different species of birds bring grace and song to the Arctic, sometimes all of them in one location. Some of them winter in the Antarctic if you please – perhaps never in their lives seeing the darkness of night. One character, a small thrush, goes to Africa for the winter!

The summer visitor to the Canadian Arctic is always impressed with the birdlife of that vast region. The Arctic is one of the most important regions for the production of ducks and geese. Some of the largest sea-bird colonies in the world are found on the steep cliffs of arctic islands.

There are about eighty species of birds known to breed in the Canadian Arctic. This is about twelve per cent of the total number of species inhabiting the North American continent. It is not unusual to find nearly all of those eighty species in one particularly favourable location.

Many arctic birds nest in colonies and compensate for their lack of variety by having large populations. If I should name a few localities in the Canadian Arctic which have especially large communities of birds in summer, I think of the Mackenzie Delta, the luxuriant valleys of Bylot Island and the turbulent waters of Hudson Strait. Even in winter, the Arctic is not entirely empty of bird-life. Sea-birds may occur all winter at the edge of the ice in the large bays and straits. Even at the highest latitudes, it is not unusual to find the track of a ptarmigan or hear during the darkness of the winter night the croak of a raven.

Some arctic birds have special protection from the cold. Examples are the dense body-down of the eider ducks and the feathered legs of the ptarmigan. The loose feathers of birds provide excellent insulation. Since there is little circulation in the legs and feet of birds, extreme cold weather in itself is not a hazard. But for most arctic birds, the winter and darkness seal off their food supplies so that they must migrate.

The most relentless factor affecting arctic birds is time. They must time their arrival on the breeding grounds so that both food and nesting sites are available. They must lay their eggs and raise their young with little delay so that the young are capable of flight before the food supplies are cut off. There is rarely the opportunity for a second brood, if the first is not successful.

Two of the greatest hazards to the nesting success of arctic birds are bad ice years and concentrated predation. In some years the ice may not break up in parts of Davis Strait until late summer. In such years, the sea-birds find their food supplies too far away from their nesting cliffs and fail to breed. In years when lemmings are scarce, foxes, owls and jaegers play havoc with nesting colonies of land birds. Fortunately for the welfare of arctic birds such disasters rarely occur two years in succession and never in all localities at the same time.

Most arctic birds arrive on the breeding grounds on the very heels of spring. As a rule, they arrive in rather noisy flocks. Most of them are already paired but nevertheless the first few days on their traditional nesting grounds are very active ones. If the nest sites are accessible, they lose little time in claiming territories and beginning to raise their families.

Most arctic birds are white, black and white, or in combinations and shadings of those colours. There is none of the fancy plumage or colour combinations which are found in birds of the forests. Pair formation and the staking out of territory by arctic birds is carried out by aerial and water displays rather than the display of elaborate plumage. The aerial acrobatics and the thrilling songs of the shore birds provide the arctic tundra with a great part of its peculiar atmosphere. Three quarters of the Canadian Arctic birds are adapted to an aquatic or at least a sodden habitat. This large group carries out their displays on or even under the water.

Most nests of arctic birds are mere unlined scrapes in the tundra which require but a few minutes to make. Some species do not even take that trouble but lay their eggs on bare ground or rock. With the exception of the ducks and geese, most arctic birds postpone their annual molt or feather replacement until fall migration so as not to interfere with the care of their young. The ducks and geese shed their essential flight feathers all at once after the young are hatched. By the time the young are able to fly, the adults have also regained their flight and so they are able to remain in family units. Those are several of the economies to which arctic birds have become adapted.

All arctic gulls are white or nearly white. They vary greatly in both their nest requirements and their distribution after the breeding season is finished. The ivory gull remains in the Arctic all winter at the edge of the open sea. The most abundant of all arctic gulls—the kittiwake—wanders over the entire North Atlantic during the winter. One of the smallest of the gulls, the arctic tern, undertakes the longest migration known of any bird. It winters in the Antarctic. It is possible that some individuals have never known the darkness of night. An adult which winters in the Antarctic must make a 20,000 mile annual flight to breed in the Canadian Arctic.

The most abundant sea-bird in the Arctic is the thick-billed murre or akpa. They are superficially like penguins both in their colouring and because they walk upright. In fact, they occupy the same niche in the arctic seas as do the penguins in the south polar seas.

The murres' wings are very short and narrow and they obtain most of their food by actually flying under the water.

The land-coming of murres to their traditional nesting cliffs is an exciting event in spring. At first, they fly in wedge-shaped flocks closer and closer to the ledges. Finally a few of the more experienced birds settle down and within a few days complete contact with the land for another season has been made. Murres carry out intricate and beautiful joy-flights and under-water dances during those first few days. It is believed that those activities stimulate breeding so that the majority of eggs are laid and the young raised in a short period.

The exodus of the murres from their nesting cliffs is also an exciting event. The adults congregate at the base of the cliffs and set up a continuous calling. The young chicks, still unable to fly, and sometimes on narrow ledges one thousand feet above the sea, hurtle off the ledges into the water. They are unhurt and soon are led out to sea by the adults. Three years or so will pass before the young birds mature and return to the land once more.

I have been asked several times if penguins would survive if introduced to the Arctic. First of all the niche in the polar seas and the North Atlantic to which we would introduce them is already occupied by the murres and other auks. Penguins would be in direct competition with them. But there are at least two other reasons why such an introduction would be impracticable. The first is that penguins are adapted to breed in the antarctic summer which is actually our winter. The other is their extreme vulnerability while on land or ice. There are no land predators in the Antarctic and for that reason penguins have never developed the power of flight. I can well imagine the havoc a few foxes or a polar bear would do to a colony of helpless penguins. As a matter of fact, some years ago penguins were indeed introduced to the European Arctic. They survived for a few years but did not breed.

Because of relatively recent and extensive glaciation, most of the Canadian Arctic is a new region for birds. New species are still immigrating northwards. The most spectacular emigration of land-birds in the Canadian Arctic right into the Polar Basin is along deltas and in wooded river valleys. The Hudson Bay lowlands is quite a recent land area. Many truly arctic birds still nest on these lowlands—arctic loons, snowy owls, oldsquaw ducks and golden plovers, for instance, but robins, fox sparrows, pintail ducks and other more southern elements also now occur. As we go northeast—especially to Baffin and the Queen Elizabeth Islands we find that the boreal elements have not yet reached those regions and the truly arctic species have the land all to themselves.

Apart from southern birds which are gradually immigrating to the Arctic as conditions improve for them, there is also an immigration of birds both from Asia to the Yukon on the west and from Greenland to the eastern Arctic. An interesting case is a small thrush called the wheatear. The wheatear is widely

distributed in northern Europe and its eastern population has also penetrated the western Canadian Arctic. They return in winter to Asia. There is a very wide belt across northern Canada —most of it in fact—in which wheatears do not occur but we find them again in Labrador and Baffin Island. This particular population returns to the Scandinavian countries and then on to North Africa where they winter. The interesting thing is that each spring those wheatears try to take a short cut across the North Atlantic to Labrador and Baffin Island. At that time of the year they come aboard ships far out at sea and it is likely that most never quite make this hazardous short-cut. In some years wheatears are very scarce in the eastern Arctic. If eventually they abandon their traditional wintering grounds in Africa and begin to overwinter in southern Canada, then their success as pioneers will be firmly established.

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DR. T. N. FREEMAN

8: . . . and Butterflies and Beetles too!

Even the study of insects has a place in the sum of knowledge we must attain if we are to be at home in the North. Consider the arctic flea – when the gulls migrate south for the winter he stays home and waits for their return in spring. There are 60 different species of beetles – and worms that live on glaciers.

The insects of northern Canada are abundant, both in the number of different species and often in the number of a particular kind. Many groups such as the dragon-flies, grasshoppers, most of the bees, and many species of butterflies and beetles do not extend their distribution north of the limit of trees. Just south of the tree-line there are about 10,000 species whereas north of the trees there are only about 500 species. This tree-line divides the distribution of northern insects as rigidly, suddenly and effectively, as if it were a great high wall. North of this tree-line is the true arctic region, and I shall tell you something about the insects of this vast area.

During the short, arctic summer, the tundra is often teeming with countless thousands of mosquitoes. Usually these are the insects that are noticed at first because of their persistent annoyance to man, although actually they are not the most abundant insects by any means. Before discussing them in more detail, I should like to make a few general remarks.

Until a few years ago, very little was known about the insects of the Arctic. However, in 1947 the Defence Research Board,

Department of National Defence, and the Division of Entomology, Department of Agriculture, organized an insect survey of the North. Since that time about seventy expeditions have collected the northern insects from Nome, Alaska, across Canada to western Greenland. For the past two summers we have had a party of six entomologists, a nematode specialist, and a botanist engaged in ecological or environmental research on insects at Lake Hazen, northern Ellesmere Island. They also made life-history studies. Because of the short arctic summer, many insects require several years to complete their life cycle from egg, through the several larval stages, to the adult. However, as very little was known about this, and many other insect activities, the Lake Hazen studies were designed to find out how some of the arctic insects live and what they do.

I shall now discuss rather briefly the major insect groups in the arctic region east of the Mackenzie Delta.

The flies are the most abundant insect group in the Arctic both in the number of different species, and in the number of individuals of a species. Among these, the midges far outnumber any other insect group. They are represented by about 150 different kinds. The larvae of most are aquatic, but several live in the sedge meadows. A few are terrestrial, and are borers in mushrooms. They do not bite man.

The next largest fly group is the root-maggot, comprising about a hundred species, whose larvae feed on the roots of terrestrial and semi-aquatic plants.

Although there are only four species of arctic mosquitoes, they perhaps rank third in insect abundance because of the large numbers of individuals. The males feed only on plant juices, particularly the nectar of flowers. The females normally feed on plant juices, but seem to suddenly lose their memories in man's presence and become avid blood-suckers. They will feed on any warm-blooded animal.

The crane-flies, as the name implies, are large, very long-legged flies whose larvae are aquatic or semi-aquatic. The grotesque, conspicuous adults are frequently seen flying over water on a calm evening. There are about a dozen arctic species.

Although black flies are very abundant and troublesome near the tree-line, there are only seven arctic species. As a rule, these do

not bite man, although at times a small cluster of them may fly around your head. The larvae live in rapid streams.

There are four kinds of hover-flies, mostly brightly coloured. The adults hover or appear to hang in mid-air in the sunshine in calm weather.

There are two species of blow-flies whose maggots feed on carrion, and one warble and one bot-fly attack the caribou.

The parasitic wasps are the second major order of arctic insects. There are two different groups of these wasps and together they comprise about 175 species. The larvae are parasitic on the larvae of butterflies, moths, flies, and sawflies. They are mostly small insects, not usually noticed by the casual observer, but are largely responsible for the natural control of the insects they feed on.

The sawflies are relatives of the wasps and there are about twenty-five species. They are called sawflies because the females have a saw-like structure connected to the egg-laying organs, and they actually saw a groove in the bark of a twig where they deposit their eggs. They are mostly small, dark in colour, and not very conspicuous. The larvae feed on the leaves of various arctic plants particularly the willows.

The bumblebees are the only true bees in the arctic region. There are only four species, but they are very conspicuous and thus frequently seen. They gather nectar and make a small amount of honey. The workers and males die in the fall and only the queen over-winters to start a new colony in the spring. The queen of one species makes no nest of its own but invades one already established by another kind, overpowers the other queen and lays its eggs in the other's nest. The workers of the other's nest look after and house the invaders' young who are only queens and males. There is no need for workers, because the dethroned queen has already provided for them. It seems to me that someone got "stung" in this case.

To those who think of butterflies as delicate, dainty creatures of sun-lit glades, it may surprise them to know that there are twenty different kinds in the Canadian Arctic. There are also about forty different species of moths and together they represent the third most abundant insect group in that region. Butterflies are

very abundant in many areas, and on warm days they can be seen flying all over the place. They are represented by the Sulphurs, Arctics, Alpines, Lesser Fritillaries, a Copper and a Blue. The Eskimos call them *ta-ka-lee-kee-ta,* which means "spots on the wings". The caterpillars feed on the leaves of a variety of arctic plants.

Unlike the moths of the south, that are night-flyers and have large eyes, the moths of the Arctic have small eyes as a rule, and fly in the sunlight, or when the sun is low on the horizon near midnight. They are rather small but swift flying moths that can fly easily against a stiff breeze. They also feed on the leaves of arctic plants.

It is interesting to note that many of the arctic butterflies, moths and other insects were first collected by the expeditions of the early arctic explorers, and the Latin names for some of the insects are *richardsoni, rossi, fieldeni, franklini, baffinensis,* and *hanburyi.* Many of the specimens they collected are still in good condition and are in the British Museum of Natural History in London, England. If these specimens had the power to speak to us—what a story would unfold of the privations, trials and tribulations of those hardy collectors.

About sixty different species of beetles occur in the Arctic. They are represented by water-beetles, ground-beetles, and rove-beetles. There is also one species of a carrion-beetle that is usually found under the carcass of a dead animal, under which they lay their eggs.

There are about fifty different species of spring-tails in the Arctic. They appear as minute dark specks which jump about when disturbed. They are grotesque creatures which, when at rest, keep their so-called "tail" curved under them and jump by suddenly straightening it out. They are often found on the land, on the surface of quiet pools, or on the snow in early spring. Because of their minute size, they are not frequently noticed.

There are six species of arctic fleas, each of which is specific to a particular animal host. They occur on the lemming, weasel, arctic hare, Parry's ground-squirrel and gulls. The gulls migrate south for the winter, but the fleas stay home and wait for the gulls to return in the spring.

Although spiders are not insects they are related to them, and several species occur in the Arctic. They are frequently found under loose stones in well drained areas.

There is one other group that also are not insects—namely the ice-worms. They have formed the subject of arctic poems and ballads and are often thought of as a myth. Nonetheless they do exist and are small black worms closely related to the earth-worm, or common fish-worm. They live on the surface of glaciers in Alaska and other places.

May I leave the thought that the Arctic, known for its ice and snow, can also boast about the buzzing of the bees, and the myriads of butterflies sipping nectar from the flowers in the meadows.

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DR. A. E. PORSILD

9: Plants in the Arctic

How can tiny flowers and plants flourish in so harsh a climate – and even provide nourishment for animals? There are 800 species of flowering plants in the entire Arctic and about 500 of these are found in the Canadian Arctic.

Plant life everywhere in the Arctic is too sparse and too dwarfed and poorly developed to make any considerable contribution to the food supply of man. Only a few arctic plants produce edible and nourishing roots and stems, and only near the southern fringe of the barren grounds are there some that regularly produce small edible fruits. All plants, however, no matter where they grow, have some food value, and many, especially those that are green, are potential sources of vitamins. But this does not mean that plants play an unimportant part in the arctic economy, for there, as elsewhere in one form or another, the solid bottom of the food pyramid of all animals including man, are the plants.

No one who has visited the Arctic, or lived there and has experienced the joy of seeing the first spring flowers appear after the long arctic winter will underrate the aesthetic importance of wild flowers in the arctic landscape. And finally, to the scientist, the geographic distribution of plants in the Arctic, how they manage to survive and reproduce offers numerous and quite intriguing problems. Let us examine, if only very briefly, some of those problems that are of particular interest to me.

There are a number of reasons why plants are not evenly distributed over the earth. Some of the most obvious ones and best known are temperature, moisture and soil. Thus in Canada, the tulip tree, the redbud and the pawpaw, to mention only a few,

are restricted to southern-most Ontario, where winters are mild because of the southern latitude and the tempering influence of the Great Lakes. If planted elsewhere in Canada, in a more rigorous climate, these trees might flourish for some time, but sooner or later would be killed by winter frost. Conversely, many arctic plants, if transplanted to botanic gardens in the south, might survive for some time, but few would produce flowers and fruits. The most serious troubles that these plants would experience would stem from the mild winters that, so to speak, would fool the arctic plants into producing new growth and flowers, when they ought to remain peacefully dormant until next spring. However, the north-south range of some plants is not controlled by temperature alone, but also by the length of the day. Some plants, especially those of the tropics, do not flower or fruit when the hours of daylight exceed twelve. Nursery men, who grow poincettias, or cinerarias in greenhouses, know this very well. Many arctic plants, on the other hand, require a long day, and even continuous daylight, in order to produce flowers and mature fruits.

Groups of plants of similar soil and climatic requirements or tolerance often grow together in what botanists call plant communities. The northern hardwood forest, for example, the boreal spruce forest, or the assembly of plants inhabiting peat bogs or sand dunes are examples of plant communities that are controlled by temperature, soil or moisture.

Another, but much less understood reason why plants are not evenly distributed, even though climate and soil may be suitable, is closely connected with the history of the land on which they grow and with their own history which, for many species, may extend into the distant geological past. From the fossil remains of plants and animals, preserved in rocks, in coal beds, or in peat bogs, we know that the climate over large parts of the earth once was warmer and perhaps more uniform than it is today. However, at the beginning of the Pleistocene period, more than a million years ago, a general and gradual increase in moisture accompanied by a decline in temperature, caused large masses of ice to accumulate in various parts of the northern and southern hemispheres. In North America and in northern Eurasia, land-ice many thousands of feet thick developed and spread from

various centres, destroying all plant life and animal life in its path. During the several phases of the Pleistocene period, converging ice masses at one time or another covered nearly all of Canada, excepting parts of central Yukon and the northwestern islands of the Arctic Archipelago, as well as some isolated areas in the Rocky Mountains.

With the retreat of the ice, the land again became available for plants and animals. The present-day distribution of plants and animals on the land that was once covered by the ice can tell us a lot about their history, and from where they invaded the lost territory.

When the ranges of the plants of which the flora of Canada is composed are plotted on maps, it becomes at once clear that the species may be sorted into groups having similar ranges. Climate, soil and topography affect the local ranges of the species within these groups, but the groups themselves clearly have a common historical background. Some groups have a distinctly eastern, and some a distinctly western range, others are wide-ranging, whereas still others are peculiar or endemic to smaller and restricted areas. Some plants of eastern North America are found also in eastern Europe, and in the same manner, large numbers that are found in northwestern America are restricted to the northwest, and to eastern Asia. Among the flowering plants and ferns, nearly half of those represented in the flora of the Arctic in Canada, amounting to about 500 species, are of circumpolar range, as are many inhabiting high mountains in more southern latitudes, wherever life conditions may be suitable for arctic plants. The intriguing question is: did they survive the ice ages in the high mountains, and if not, where did they come from?

Plant life, as we know it today in the polar regions, in a good many respects, resembles that found in the alpine regions of more southern latitudes, and several life-forms and a great many species are common to the Arctic and to mountain ranges more than a thousand miles to the south. The principal physical difference is in the length of the growing season, but even this difference is more apparent than real, for on high mountains the accumulation of snow is often so great that the effective growing season approaches that of the Arctic. Above timberline at Banff in the southern Canadian Rockies, the collecting season for the

botanists is approximately from July 1st to August 15th or very closely that of the somewhat lower mountains west of the Mackenzie Delta, 16° of latitude north of Banff, or for that matter, to the collecting season for most of the Canadian Arctic.

In the polar regions, particularly in the central parts of large land masses or islands, precipitation is very light, often totalling less than seven inches for the year. The winter snowfall is sparse, and frequent gales sweep the snow off the level ground, exposing the plant cover to the harmful drying effect of the wind. So small indeed is the total annual precipitation in some parts of the Canadian Arctic that were it not for the fact that the soil remains perpetually frozen a few inches below the surface (permafrost), thereby preventing the surface water from penetrating to depths beyond the reach of the plant roots, most of the high Arctic would be a lifeless desert.

In the Arctic the vegetation, to be sure, is much affected by the severe conditions under which the plants must grow. The shortness of the growing season, however, and the deficiency of soil and precipitation have a more marked effect, perhaps, on plant life than has the relative lowness of the temperature of the air surrounding the individual plant.

Due to absorption of solar heat by the dark-coloured soil and its vegetation, the actual micro-climate in which arctic plants live may at times be as much as 25° or even 40° (fahrenheit) higher than that of the air, as recorded at a nearby weather station. In northernmost Greenland, in latitude 82° 29′, during the month of May when the air temperature at noon was 10° F., a temperature of 38° F. has been recorded among the dead leaves of a saxifrage, and 50° F. inside a cushion of dark coloured mosses. Here then, we have the answer to the apparent enigma: how can plants in the Arctic grow and flower with air temperatures barely above freezing? Because of insulation, temperatures high enough for photosynthesis may actually exist near the ground or within the plant cushion, when the air temperature a few feet above the ground is several degrees below freezing. During periods of unfavourable weather, the growing parts of the plant may actually freeze, but they are not destroyed. In this manner the effective growing season of arctic plants is prolonged very considerably

beyond the number of days "without freezing temperatures", as recorded by the meteorologist.

Owing to poor drainage and poor aeration—both partly due to the low soil temperatures—arctic and subarctic soils are commonly acid. For the same reason organic decay by bacterial action is extremely slow, and consequently the sources of available nitrogen, as well as other salts needed by the plants, are frequently deficient. In a few places in the Arctic—such as bird cliffs, animals burrows or near present or past human habitations—where nitrogen and phosphate are available in abundance, many arctic plants respond by lush and rank growth.

It is in adaptation to the short arctic summer that almost all truly arctic plants are perennial. Summer is too short to complete a life-cycle in one season. The failure of just one seed crop might be fatal for the survival of the species, at least in a local population. Most species require many years from germination to the first crop of flowers. Many do not depend entirely on seed production, but are protected against unfavourable seasons by various means of vegetative reproduction. In the Arctic the specialization of plants is mainly geared toward survival against a very harsh climate. In the Arctic, there are neither climbing plants, plants that sting or poison, nor any that are protected by spines or thorns. The implication is, of course, that no such protection is needed in the Arctic. A great many arctic plants on the other hand, are xerophytes, that is, plants that are adapted to withstand prolonged drought by having rather small, often leathery leaves, or having leaves and stems that are covered by densely matted hairs, providing a felt-like covering for the stomata through which the plant breathes and loses moisture.

By their low and compact growth habit, most pronounced in the so-called cushion plants, arctic plants are well adapted to resist desiccation and mechanical abrasion by wind or by drifting sand or snow. As a further protection against desiccation rather than low temperatures, the wintering buds of many arctic plants are placed just below the surface of the soil or hidden among the persisting leaves, leaf-stalks or stipules of former years. Widespread vegetative reproduction is accomplished in a number of ways; by adventitious buds in the leaf-axils as in some chick-weeds and saxifrages; by offsets, as in the runners of a strawberry plant,

in the arctic yellow saxifrage, commonly called the "spider-plant", and in some species of willow-herb; or by special kinds of buds or bulbils that appear in the place of flowers as in some knotweeds and saxifrages. Others again have widely creeping rootstocks and runners.

Thanks to their wintering buds many arctic plants require a remarkably short time to awaken from winter dormancy, come to bloom, mature fruit and again prepare for next winter.

Spring comes with a rush in the Arctic. The snow seems almost to disappear as if by magic—most of it actually evaporates—and long before the last drifts have vanished, the first flowers appear. Near one of my camps, near the mouth of the Mackenzie Delta, the so-called "prairie crocus", or pasque flower, which is really an anemone, began growth on May 15th, when a thin crust of snow still covered the plant. On May 25th, the large bluish-purple flowers appeared from among last year's dead leaves, and on June 25th the seeds were already dropping.

Early in August, most of the truly arctic plants have completed their seasonal life cycle. While their seeds are maturing, new leaf-buds and flower buds develop near the surface of the soil, well hidden among the dead leaves, while food is being stored in the subterranean stems or rhizomes, or in the root systems, in preparation for next season's growth.

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V. F. VALENTINE

10: Anthropology

That rather frightening title means "the whole science of man", the study of what he has been and is, anywhere, from the beginning of time until now. This article and several others focus on the Eskimo and Indian as people deserving the wisest help we can give them in their step from the ice age to the atomic age.

As its Greek name implies, anthropology is the study of man—man as a physical being as well as a member of society possessing a culture. So far as we know man is the only creature who possesses a culture. It is this unique fact which intrigues the anthropologist, and he spends his time describing, analysing and comparing the many different kinds of cultures which men have produced throughout the world in ancient as well as modern times. The whole world, in a sense, is his laboratory. With his pencil and notebook, or trowel, shovel and measuring tape—for these are his main tools—he may be found in Asia, Africa, the remote parts of America or for that matter a small city or town in Ontario or Massachusetts, studying the way of life of the people living there.

Most of the archaeological and physical anthropological research carried out in the North is by scientists employed by the National Museum of Canada.

Over the past nine years the Northern Co-ordination and Research Centre of the Department of Northern Affairs and National Resources has sponsored a number of social and cultural anthropological research projects in the North. This it does mainly

by hiring scientists from universities across Canada. The research falls into three main types:

First there are studies of the adjustment of Eskimos and Indians to encroaching white civilization, particularly those Eskimos and Indians who are leaving the life of the land for a life based on wage employment in the larger settlements of the North.

The second are studies of the traditional cultures and societies of the still isolated Eskimos and Indian bands.

And the third are studies of the large modern communities such as Inuvik, Yellowknife and Whitehorse. As I mentioned earlier, the anthropologist is interested in all mankind, not just people who are socially or culturally different from him.

One of the most interesting developments in the North in recent years has been the move of nomadic Eskimo and Indian bands from a living based on hunting, to a stationary one in town based on wage employment. We know from previous accounts about these people that as hunters they lived in make-shift houses and travelled about the country-side in family groups. Sometimes three or four families would cluster together to form a band. There were no strong leaders. Each family head was the boss of his particular family and the work of everyday life—that is the providing of meat, clothing, fuel and a place to sleep—was performed by a man, his wife and perhaps older children. No one in the band was a specialist in the sense that he provided all the meat for the others in return for some services or goods, or she the clothing. Each family provided goods and services for itself. There were no garbagemen, postmen, tailors or butchers who formed a specialist group. Neither were there professional teachers. The young man learned to be a hunter from his father, the young woman a wife from her mother.

In the new towns or settlements which are developing in the North this type of social life is no longer possible.

A father who works for wages cannot hunt, a woman must rely on the store for clothing, fuel and food, children must go to school to broaden their knowledge, the household becomes a residence for one family. The old values, the customary way of living developed over centuries, give way to the demands of organized community life where the labour of daily life has to be divided up across family lines, and vital services provided by

trained men, be these for sanitation, education, the production of goods and so forth. Quite naturally, the process is confusing for some and for these adjustment is quite difficult.

It is to try to find the gaps which exist between the old way of life and the new, and to suggest possible methods of bridging these gaps, that our research in anthropology is aimed under this type. We have found, for example, that frequently although an Indian or an Eskimo man may earn a good income, he and his family have poor dietary habits. Not being used to storefoods he may buy items with little or no food value, and he is no longer able to supplement his diet with the nourishing foods once obtained from the land. There are of course other aspects of the situation being studied, ranging from the remarkable way in which many Eskimos and Indians are tackling their own problems and finding solutions to some of these through the formation of commercial co-operative and other organizations in several parts of the North, to the problems posed by excessive drinking of alcohol, and in some cases, the rise of juvenile delinquency in the larger settlements.

The second type of study is the study of Eskimos and Indians living after the traditional fashion off the land. This is really related to the first type, for if we are to have an intelligent appreciation of what problems are being posed for these people when they move to town we must know something about their background.

The third type has just recently started. It has often been said that Canada's future lies on the frontier. Yet we know so little about the kind of societies being built on the frontier and less about the people from southern Canada who form them. In places like Yellowknife or Inuvik for example, our research workers are asking numerous simple questions of which the following are a few:

1. From what part of Canada does the bulk of the population come?
2. Is it a young population with few old people? How frequent is the population turnover?
3. What do people do for entertainment or recreation?
4. Where do they work and what is their average income?

5. To what extent do they participate in local affairs, form clubs or benevolent associations?
6. How long does a person have to live in one of these settlements before he or she calls it home?
7. Do most of the young people who go "outside" to college and universities return or do they stay outside, and if so why?
8. Where is "outside" anyhow?

Someone once said about the North, "Now that the Eskimos and Indians are becoming sedentary, the white man has become nomadic." Among other things we hope our studies will reveal how true this is.

Today, all over the world societies and cultures of the so-called primitive man are undergoing change at unprecedented rates. At no time in our history have we been more pre-occupied with bringing benefits of western civilization to those parts of the world less fortunately endowed than ours. Tremendous sums of money, time and effort are now being spent to alleviate poverty, to increase educational opportunities, and to improve health standards.

Unfortunately, in too many instances the programs we have designed to meet these objectives have failed in spite of our good-will, hard work and planning. In too many cases the failures can be traced to a lack of knowledge of the culture of the people involved, to insufficient appreciation of the complex adjustment problems posed for them as a result of radical social and economic changes.

The social anthropological research sponsored by the Northern Co-ordination and Research Centre attempts to avoid this sort of thing happening in the North by providing the northern administrator and legislator with adequate knowledge of the cultures involved.

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The People

17

Like all boys the young Eskimo wears his pants out at the knees, but his are patched with bits of fur.

8, 19 The Canadian Eskimo—"No other people have ever wrestled with the polar regions as they did—and survived". Dr. Jenness, Dr. Harp, Graham Rowley and Dr. Lefebvre write about their past and future.

The boats will stand ice-fast for perhaps nine months of the year, but a boy and his sled are never still.

21

Ruins of a Thule culture winter house, Creswell Bay, Somerset Island. Here are the collapsed remains of a semi-subterranean single roomed house built about 1500 A.D. Such houses were generally made of stone slabs and sods over a whalebone framework. Several fragments of whale jaws are visible between the Eskimo and the haversack. The two long curved bones resting in the entrance passage are from the lower jaws of whales.

First catch your seal, then skin it, scrape it, clean it, stretch it—and from then on it can become Eskimo boots or a new mode in milady's wardrobe.

The stone carvings, drawings and prints of the Canadian Eskimo have recently placed the Arctic on the world's art map—some seem primitive, some so simple as to be sophisticated. Here is Kiakshuk, an artist at Cape Dorset.

24

25

24 The dogs who brought him to the hunting place in the Keewatin stand by for their share of the spotted seal.

25 Eskimo mother and child.

DR. ELMER HARP, JR.

11: World Arctic Archaeology

Probably as much as 70,000 years ago man began living in the Arctic, fashioning the bone weapons that killed the animals that gave him food and clothing. But "throughout many years to come, every expedition to the far North will hold the promise of fresh and exciting discoveries".

The topic "World Arctic Archaeology" has many connotations, of which the foremost, perhaps, is the obvious thought that there are scholars who seek by means of archaeological science to learn about the lives of the primitive men who occupied the arctic zone in prehistoric times. Indeed, this is quite true. All modern countries whose territories verge upon, or include, the Arctic, that is, Norway, Sweden, Denmark, Finland, the Soviet Union, the United States, and Canada, have specialists in this field, and in each of these national realms are found the remains of such aboriginal men. However, the pursuit of archaeology in the Arctic is essentially no different than elsewhere in the world. It employs the same scientific techniques for recovering information from the long-dead past, and is concerned with understanding the common problems that have faced the human species in all climes and in all times. Therefore, I like to regard man's arctic story in the broadest possible perspective, integrating it with his total culture history, even in the subarctic regions of the world.

Since the time of Pytheas the Greek, some 2300 years ago, men from Europe and their recent New World descendants have not only girdled the earth in an east-west direction, but have also explored the trackless lands of the far North. For centuries the

tempo of their northward movements was sporadic, yet slowly they acquired knowledge and techniques which helped them attain one of the ultimate geographical goals, the North Pole. This was slightly more than fifty years ago.

It is also a matter of record that in historic times wherever civilized man laboriously sought paths into arctic lands, he usually found other men already there to meet him—primitive, indigenous men who knew how to live with a relatively high degree of security and efficiency in their uncanny cultural adaptation to the severe, circumpolar environments.

Thus, the spectrum of man's life in the North shows two modes of successful accommodation: the modern approach which depends essentially on logistical lifelines to the outer world of civilization, and the aboriginal, subsistence approach that is compounded in many-facetted ways from man's primitive past.

The human being did not originate in the Arctic, nor, as a skinny, furless animal, is he biologically well fitted for existence there. Nevertheless, over countless millennia, his increasingly predatory activities gradually led him northward out of warm climates. Given our present knowledge of the palaeo-climatology of the Pleistocene period, we can be reasonably certain that some early hunters of western and central Europe were living in the periglacial zone, on the fringes of wintry weather, possibly a quarter of a million years ago. Even before this, in middle Pleistocene times, primitive Pithecanthropoid types in China, called Peking Man, were living in caves and using fire. This is fairly good evidence of adaptation to cold, and in a very real sense, I believe, the beginning of man's conquest of the Arctic can be traced to that remote time. However, he was then still a creature of temperate climates, and his rudimentary culture was as yet no match for the rigors of the high Arctic.

It is especially interesting to note that some authorities believe that Peking Man was a forerunner of the Mongoloid racial stock, and, according to one current theory the Mongoloids have evolved certain biological adaptations in response to the cold of high northern latitudes. Although this type of adjustment has not been proven, some groups of arctic Mongoloids, the Eskimos among them, do exhibit features that undoubtedly protect them against cold. For example, being short and stocky they have a lowered

ratio of skin surface to body mass, and therefore radiate less body heat. The same effect is observed in their relatively shorter arms and legs, and there is physiological evidence that a special circulatory mechanism further minimizes heat loss through hands and feet. The low-bridged nose, narrow nasal passage, and liberal fleshy covering of the face, including the Mongoloid eye-fold, all seem to afford additional protection against cold.

Culturally speaking, however, it was toward the end of the Paleolithic, or Old Stone, Age, beginning perhaps as far back as 70,000 years ago, that man truly had learned the art of cold-weather living. From the Aurignacian, Solutrean, and particularly the Magdalenian periods, rich archaeological finds testify to his increased capabilities. He had developed highly diversified and specialized tools and weapons of chipped stone, including implements for scraping and preparing skins. He had needles as well as buttons of bone and ivory, so that we can infer the use of protective garments. If final proof were needed to show that man could thus adapt himself to the cold, we have the animal remains from his dwelling sites and the magnificent rock paintings that are bequeathed to us in the caves of southwestern Europe. The game he hunted and represented in his art was characteristic of cold climates; muskox, rhinoceros, the mammoth, cave bear, and seal.

These Upper Palaeolithic men ranged across the Eurasiatic land mass, and their widespread culture base in the middle latitudes gave rise to succeeding generations of hunters who pressed slowly northward after the retreating glaciers. Some time, too, in the closing phases of the Pleistocene, the northern hunters crossed into the New World, and at last, by the year 2000 B.C., man had fully conquered the circumpolar Arctic, from Norway to Greenland. Quite as important as the accomplishment itself is the fact that he did it with the tools, weapons, and techniques of stone age culture.

In North America, arctic prehistory is confusingly compounded of both Indian and Eskimo elements and, despite a marked increase in archaeological field research there during the past twenty years, only the bare outlines of man's conquest of the circumpolar regions are known. In tracing these through Canada it is helpful to distinguish several geographic divisions which, although linked by common prehistoric culture bonds, have their own peculiar histories.

In the eastern Arctic, for example, we may include northern Quebec, Labrador, and the island of Newfoundland, even though the latter province lies within the subarctic boreal forest region. The earliest inhabitants there were Indian groups who diffused along the Gulf of St. Lawrence into the southern portions of the area some four to five thousand years ago. However, the northern, arctic fringes of this area were first inhabited by a people whom we regard as proto-Eskimo, for they subsisted by hunting both on the tundra and along the arctic coast. Also, their technique of manufacturing chipped stone tools appears to have derived from very early cultural horizons in the western Arctic. At a still later date we find the Dorset culture widespread throughout the eastern Arctic, and this was the first phase that can positively be identified as Eskimo. For example, the Dorset people used the harpoon complex for seal and walrus hunting, although they probably did not hunt whales, and they did not have the domesticated dog. They were ultimately supplanted by various groups of true, or classical, Eskimos who further perfected the practice of sea mammal hunting. Then, in the final stages of the prehistoric continuum, we find the Vikings, known from their first settlements in southwest Greenland, and just recently, from the discovery of their occupation at L'Anse aux Meadows, on the extreme northern tip of Newfoundland.

A second major archaeological area, the central Canadian Arctic, is comprised of the islands of the archipelago and the coastal fringes of the Northwest Territories. Generally, the prehistoric occupation sequence there was much the same as in the eastern Arctic, although we have not found traces of early Indians so far north. The first level is the basic proto-Eskimo culture with Alaskan affinities, and this is followed by the Dorset culture, and the later classical Eskimos.

South of this area is the great Barren Grounds triangle which lies north of the tree line and extends from the shores of Hudson Bay almost to the mouth of the Mackenzie River. Some theorists have proposed that the Eskimo and his culture originated there, but recent field researches have shown beyond doubt that the earliest inhabitants of this inhospitable region were in fact Indians who, beginning at least 5,000 years ago, came in summer hunting parties to exploit the vast caribou herds. They, or their ancestors,

were former bison hunters who had simply transferred their communal hunting techniques from the Great Plains to the northern Barren Lands.

The western Canadian Arctic, from Coppermine to the Alaskan border, poses a different set of archaeological problems. In the upper, or latest, levels of the occupation sequence, we find various traditional manifestations of modern and recent Eskimo culture, and preceding these are suggestions of developmental stages that relate more closely to Alaska and the Old World. Then come the familiar proto-Eskimos, and still earlier, beneath them, more implications of close relationship with the Old World.

It is thus apparent that the western prehistoric culture sequence was far more complex than that known in the central and eastern regions. This can be explained by the geographic nearness of the western area to Siberia and its consequent exposure to more diversified cultural impulses from the Old World. Much of this cultural influence gradually permeated southward out of Alaska, although some of it did penetrate eastward along the arctic slope of Alaska, at least as far as the valley of the Mackenzie, whereupon it seems to have been diverted southward into the heart of the continent. Hence, although there are a number of observable relationships between the western Arctic and more southerly regions of North America, the central and eastern Arctic always remained somewhat marginal to those main currents of culture drift.

There is at least one more important characteristic of arctic prehistory: that is, a gradual shift through time from complexity to uniformity. As I have suggested, the earliest and most primitive levels of occupation throughout the North American Arctic were diversified, but as the centuries passed the true Eskimo culture evolved, increasing uniformity developed. One should not infer from this statement that all Eskimos are alike and possess an identical series of cultural traits, although their basic modes of adaptation are similar as well as their physical type and language, and hence there are strong resemblances throughout their circumpolar spread. The environment, of course, establishes a strict set of ecological conditions to which the primitive hunter must conform if he is to survive, and to some degree this must have been responsible for the cultural homogeneity we find in the Arctic. However, we cannot discount the simple movement of

peoples and also the role of diffusion and the readiness with which ideas are transferred from one human society to another.

Archaeology will some day clarify these historical problems in the North. In terms of human history, the Arctic is important and significant not only for itself, as a circumpolar zone, but also because it encompasses the Bering Strait funnel through which early man found his way from Siberia into the New World. Throughout many years to come, every expedition to the far North will hold the promise of fresh and exciting discoveries, for man's first conquest of these cold regions is one of the outstanding chapters in his total story.

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DR. J. A. HILDES

12: Man Shivers in the Arctic

"We may conclude that man would not survive naked in the arctic cold and in this respect he is very different from the furbearing arctic animals." This proposition of Dr. Hildes seems fair enough, but he proves it scientifically – so don't go there naked!

It has frequently been stated that physiologically speaking, man is a tropical animal. He has, however, ventured time and again into the cold parts of the earth. Indeed, there are races of men, notably the Eskimos, who have lived thousands of years in the arctic cold. How has man, built apparently for the tropics, adapted himself to successful living in the Arctic?

To understand this we must see how man regulates his temperature. We, along with most other mammals, are homeothermic: that means we have a fixed body temperature. Our thermostats are set for an internal body temperature of 98°F, and unless we are sick, it never moves from a narrow range of one or two degrees above or below that temperature. There are certain species of animals, the hibernators, who in the cold can lower their body temperature, sometimes almost to the freezing point, and so save the energy of keeping warm. There are other animals, the piokilotherms—such as snakes or lizards—whose body temperature depends on the temperature of their environment. When it is cold outside, they are cold and lethargic—when it is warm they are warm and active. But man does not belong to either of these two groups. His body functions independently of the climatic conditions surrounding him. This independence has great advantages but to achieve it, there are some costs. When it is too warm

outside he must do something to keep from overheating; when it is cold outside he must conserve heat or generate more heat to keep warm.

The first mechanism that goes into action to conserve heat closes down the blood supply of the skin, particularly of the hands and feet. When this happens the skin becomes cool and less heat is lost to the environment. The skin and the superficial tissues then act as insulation for the rest of the body which always remains at its set temperature; so that when we say the body temperature is set at 98°F, we mean only the internal temperature at the body core.

Increasing our insulation by cooling the skin works fine, but there are limits to its usefulness. A resting, naked man can comfortably maintain his internal body temperature by this means in a room at 75 to 80°F, which is about fifteen or twenty degrees below the set of his internal thermostat. In temperatures below that, and 75 to 80°F is not really very cold, he has to do something else. What we usually do, of course, is to put on clothes but if we had no clothes we would shiver. Shivering is a means of keeping warm. The muscular work involved produces heat which tends to raise the body temperature, and so compensates for increased heat loss to the environment. In violent shivering the heat production of the body may be more than doubled. This is a very useful thing for a short time but we cannot go on shivering for long without fatigue. Some small laboratory animals such as rats, when exposed to continuous cold conditions do raise their metabolic rate and maintain the new high level indefinitely without shivering as long as they are in the cold, but as far as we know this does not apply to man.

We may conclude from these thoughts that man—the tropical animal—would not survive naked in the arctic cold, and in this respect he is very different from the furbearing arctic land animals such as husky dogs, wolves, caribou, etc., whose insulation is so good that they are quite comfortable, and not shivering even when they are resting at forty degrees below zero.

What makes it possible for man to survive and, as the Eskimos do, maintain a successful culture, in the Arctic, is not their physiological mechanisms but their social and behavioural adjustments to the cold situation. In more specific terms, man exists in the

Arctic because he provides himself with clothing and food and shelter.

There is, of course, a world of difference between existing and living. The very existence of a city dweller dumped in the Arctic would be in jeopardy even if he had adequate clothing, shelter and heat, but the native Eskimo finds or makes all he needs for comfort from the local resources, including the snow for building a house. The difference is largely a matter of technical know-how and confidence. The Eskimo knows how to make weapons for hunting, where to get food, how to make clothes and houses.

Although this technological difference is well appreciated, physiologists have always been curious to know whether the arctic native races do not also have some physiological adjustments that make it easier for them to tolerate the cold.

There are two principal ways in which this could conceivably come about. One is by a more efficient insulative mechanism, and the other is by increasing heat production, although we have seen that there are limitations to either of the possibilities.

If we look at the insulative business a bit more closely, there are some further implications that we haven't yet mentioned. If the skin surfaces are exposed to extreme cold, having the skin act as a very efficient insulation would be disastrous. The skin would then become so cold that it would freeze, and freezing damages the tissues and they become gangrenous. If that process is severe, the frozen part will eventually fall off.

Clearly, cooling the skin to act as insulation is not in itself a likely solution to the Eskimos' problem, although conceivably, it would be a useful mechanism if conditions were not as cold as freezing. Such moderate conditions might exist under the Eskimos' clothing, and such conditions might also exist in certain areas where the outside temperature does not go below freezing. A good insulative mechanism might allow people living in such a climate to dispense with clothing altogether.

The other mechanism, that of increasing heat production, also bears a closer look. We have seen the limitations to shivering, but if we could produce more heat without shivering we might have a partial solution to the problem of living in the cold.

Our metabolic heat comes from the food we eat and if we burned a lot more food—particularly fat, which has a high caloric

equivalent per pound (about twice as high as sugar or meat), we would then be more active and produce more heat.

With this background we may now look at some of the studies which have been carried out on man under cold conditions. We might look for improved insulation in people living in an area of moderate cold who do not have elaborate shelter or clothing. Rather than looking in the Arctic, central Australia was chosen for some of these studies. The Australian aborigines are a naked people who do not live in houses and yet at night, in the winter time, the air temperature is close to freezing. When they were studied, along with some Europeans to see who tolerated the cold better, it was found that the Australians rested well and did not shiver when they spent the night under a single blanket, compared to the poor shivering whites. The internal temperatures of the two groups were all within the normal range, but the skin of the native Australians did become quite cool—to a degree that would be painful to us—but which they tolerated without discomfort. Therefore it does seem that these people conserve heat by increasing their insulative use of their skin.

Let us now turn back to the Arctic. Studies carried out by Markworth at Fort Churchill showed that people used to working outdoors in that place got less numbness of their fingers in the cold than people used to working inside. It appears that in people used to cold, the skin functions better at a low temperature than is usually the case.

Similar studies to those carried out on the Australian aborigines have also been done on arctic people including Canadian Arctic Indians in the northern Yukon and Eskimos on Baffin Island. With regard to their skin temperature when exposed to cold, it was not low as was the skin of the Australian aborigines.

Incidentally, contrary to popular belief, the Eskimos do not have a thick layer of insulating blubber under their skin. Nonetheless, the arctic natives seemed to have less discomfort during a cold night than the shivering whites who were subjected to the same tests. A possible explanation of this lies in the amount of heat produced. In these tests the Eskimos were found to have a higher metabolic rate than the whites, even when the differences in body size were taken into account. This has long been a thorny problem. Physiologists in Alaska have found that Eskimos housed

in dwellings at Fairbanks, and eating a white man's diet, had the same metabolic rate as the white man, and they attribute any increase in heat production by Eskimos to diet—particularly the meat in it. Physical fitness may play a part, but the possibility still remains that living in a cold climate causes some alteration in appetite or in metabolism so that the body does produce more heat under these conditions.

Research work is still going on, but certain things are now quite clear. There is no doubt that survival of man in the Arctic is due to his mastery of the environment to provide himself with clothing, with heat and with shelter, and not because he is physiologically adapted to survive such extreme cold.

On the other hand, there are certain data which indicate that some physiological adaptation to a cold climate takes place. The problem is not a simple one and there may be several different physiological mechanisms at work to make life more comfortable for man in the Arctic.

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DR. J. ROSS MACKAY

13: Arctic Landforms

It has been pleasant and easy to read about people, animals, birds and plants. But now the layman enters the vaster but fascinating mysteries of the land, the ice, the water, the air, and the inside of the earth. Wonder takes on new dimensions.

The landforms of the Canadian Arctic are of great variety, ranging from the white, glacier-clad mountain peaks of islands in the eastern Arctic, to the monotonously flat green alluvial river-built lowlands of the mainland in the western Arctic. However, the distinctiveness of the arctic topography cannot be found in the glacier peaks nor the alluvial plains, because similar peaks and plains occur far to the south in temperate and tropical lands. The uniqueness of the arctic landforms is superficial, and confined mainly to the upper ten to fifty feet of the ground.

When the large continental glacier covered the greater part of Canada, some thousands of years ago, most parts of the arctic islands and the arctic mainland were buried beneath a sea of ice. Even today, relic glaciers cover sizeable portions of Axel Heiberg, Baffin, Devon, and Ellesmere Islands. The effects of past glaciation are everywhere apparent, especially to the air traveller.

Along coastal areas, the observer may see prominent gravelly beaches extending inland, often for distances of many miles, to heights which may exceed 500 feet. As many people know, there has been an emergence of the land, relative to the sea, since the glaciers melted away, and the high beaches record this vertical change. The beaches, which parallel the coast, are similar to

beaches along present coasts, except for their greater altitude above sea level. The ages of some of the beaches have been determined from radiocarbon dating of marine shells and driftwood, so that the general pattern of uplift of the land can now be sketched in for the past 10,000 years. In inland areas far away from the coast, the air traveller may see other evidence of glaciation, such as long flutings miles in length or sinuous sand and gravel ridges. These features are also present in more southerly parts of Canada, but are more frequently hidden from view by vegetation growth. The large flutings, which would resemble marks left by giant fingers drawn over the ground, record the direction of glacier movement. The sand and gravel ridges, which are called eskers, are the casts of former glacial streams. Some eskers are over a hundred miles long and many of them are plotted on maps of the National Topographic Series.

Most of the land area in the Canadian Arctic is underlain by permafrost or perennially frozen ground. Permafrost is a condition of the ground defined upon the basis of temperature; that is, permanently frozen ground never thaws even in the hottest time of the summer. In temperature, it is like the inside of a home freezer which never defrosts. The depth to the top of permafrost may range from a few inches to several feet, but the bottom of permafrost may be many hundreds of feet down.

In areas underlain by permafrost, the surface of the ground is frequently broken up into eye-catching geometric patterns of circles, ovals, polygons, and stripes to form what is known as patterned ground. A very distinctive type of patterned ground is the tundra polygon which is widespread in the Arctic and may be easily seen either on the ground or from an airplane. The tundra polygons resemble enormous mud cracks, such as those of a dried-up muddy pool, but with diameters of from fifty to a hundred feet. The tundra polygons may be nearly as regularly shaped as the squares on a checkerboard, but most are irregular, somewhat like the markings on turtle shells. The boundary between two adjacent polygons is a ditch. Beneath the ditch there is an ice wedge of whitish bubbly ice which tapers downwards, like the blade of an axe driven into the ground. Some ice wedges are more than ten feet wide at the top and are tens of feet deep. Such ice wedges are

probably at least several thousand years old. Eskimos frequently dig ice cellars at the junction of two or more large ice wedges. On a smaller scale, the ground observer may see stones arranged in circles or garlands a few feet across, like stone necklaces; or the ground may have stripes trending downhill. Although there has been much study on these forms, their origins are not fully understood. Most experts would agree, however, that they result from processes involving frost action.

Of particular interest to people in the western Arctic are the conical ice-cored hills called pingos, an Eskimo word for hill. The pingos are most numerous near the Mackenzie Delta, where there are nearly 1,500 of them. The pingos may reach a height of 150 feet and so are prominent features in the landscape. They are found typically in shallow or drained lakes and are believed to have grown as the result of the penetration of permafrost into a thawed lake basin. Each pingo has an ice core of clear ice. If the ice core should melt, a depression with a doughnut shaped ring enclosing a lake is left behind. In areas of fine grained material, such as silts, large horizontal ice sheets may occur. These ice sheets are usually formed of dirty banded ice, quite different from the crystal clear pingo ice. The tops of the ice sheets frequently lie only several feet below the ground surface; their thicknesses may range from five to over thirty feet. Although the mechanism of ice sheet growth is still the subject of laboratory and field investigations, they have probably grown in place by the freezing of water sucked up from below by a "wick" action. The ice sheets are best observed along eroded coasts of seas, lakes, and rivers, especially along the Yukon coast and the Mackenzie Delta area. Some settlements and airstrips are built over such ice sheets.

In conclusion, the landform features of the Arctic are distinctive only where climate can exert its influence. The major relief features of hills and valleys, plains and plateaux, are not unique. It is the skin-deep or superficial feature such as the bare raised gravelly beaches, the long parallel glacial flutings, the presence of permafrost, the widespread tundra polygons, the ice-cored pingos, and the horizontal ice sheets which impart character to the arctic landscape.

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J. E. LILLY

14: Getting It All on the Map

In the upper Gatineau region fifty miles north of Ottawa a man's line often depends on a sentence in an old will saying it ended "by the big pine tree near the creek". In the Arctic it is aerial photography, stereoscopic lenses, Greenwich Mean Time, radio signals bouncing off the Shield – and trained surveyors.

A topographic map is a symbolic picture of the area represented, with appropriate symbols on paper corresponding to shore line, streams, glaciers and other features. Elevations are shown by contour lines. A contour line is a line of constant elevation, and may be visualized as a hypothetical shore line resulting from a rise in the sea-level. For example, the 100-foot contour line represents the limit of flooding which would result if the sea-level were raised 100 feet. To a person accustomed to interpreting contours, such lines show the shape of hills and valleys.

The basic framework on which a topographic map is constructed is the geodetic control network. A geodetic survey is a survey carried out to very high accuracy, and extending over such a large area that the curvature of the earth must be taken into account in making computations. The geodetic control network is a skeleton framework of control points, and each control point consists of a mark on the ground whose position or height above sea-level has been carefully determined. Some such control framework is essential when mapping large areas, though for a small area a simple sketch may sometimes serve the purpose. Frequently separate control networks are established for vertical and horizontal control.

In the case of vertical control, elevations are determined in the settled parts of the country by precise levelling operations, but in the far North less exact methods have to be employed. Ordinary level lines may be run in the winter, or elevations may be determined by the measurement of vertical angles, or from barometric readings, or by means of an instrument known as the "airborne profile recorder". This instrument, mounted in an airplane, determines the height of the airplane above the ground surface by a method very similar to radar. Since the height of the airplane above sea-level may be determined by a barometric altimeter, and checked by flying over ocean water or over a lake of known elevation, the height of the ground surface above sea-level may be deduced. This method of determining elevations is much faster than the simple use of barometers on the ground, and gives results of about the same accuracy.

A horizontal control network consists of a series of points whose latitudes and longitudes have been determined. There are two fundamentally different ways of determining latitude and longitude—the astronomic method and the geodetic method. By the astronomic method the latitude and longitude of each point are determined independently from astronomic observations, while by the geodetic method the latitude and longitude are computed on the basis of the measured bearing and distance from a point whose position is already known. The two methods give results which may differ from each other by as much as a mile, though the greatest difference so far known in Canada is closer to half a mile. The cause of this difference is irregularity in the shape of the earth, caused by irregular distribution of matter in the earth's crust. The astronomic method has the advantage that a control point can be established anywhere without reference to previously determined points, while the geodetic method requires a gradual building up from known to unknown points. On the other hand, the distance between two points computed from the astronomic positions may not agree with the actual distance as measured on the ground.

Previous to 1950 horizontal control in the Canadian Arctic consisted of astronomic points only. The positions of these points were determined at different times and to different standards of accuracy. Some of the older determinations were quite seriously

in error, especially in longitude, which is much more difficult to determine accurately than is latitude. The determination of longitude involves the determination of local time and the comparison of local time with Greenwich time. Local time may be determined by various methods, all of which involve noting the clock time of some event such as the passage of a star across a wire in a telescope. With the best of modern field instruments and methods it is difficult to obtain results with an error of less than a few hundredths of a second. Years ago errors of such determination were generally much larger than this. But it is in the determination of Greenwich time that the greatest advances in accuracy have occurred. Today Greenwich time may be determined from radio time signals, but before the advent of radio it was necessary to resort to such methods as the determination of the position of the moon among the stars, the timing of eclipses of Jupiter's moons, or simply dependence on a portable chronometer which was supposed to keep Greenwich time. None of these older methods is capable of high accuracy.

There has also been some improvement in the accuracy of astronomic latitude determination, but the improvement is less striking than in the case of longitude work. Observation for latitude is simpler than that for longitude, consisting essentially of measurement of the altitude at which the sun or a star crosses the meridian, or north-south line.

Between 1950 and 1957 a geodetic horizontal control network was established in northern Canada. The network was built up as a series of overlapping triangles with the lengths of the sides measured by a method known as "shoran". The method consists essentially in determining the time taken for a radio wave to travel from point to point. To measure the length of a line, instruments are installed on the ground and in an airplane. The plane then flies across the line joining the ground points, and the sum of the distances from the plane to the two ground points is measured by this timing technique. After suitable corrections for meteorological conditions and for the height of the plane, the ground distance between the two points is obtained. With lengths of lines thus determined, the positions of the control points can be computed.

Today most detailed mapping is done with the aid of aerial photographs, but as recently as my own early days in surveying a map was made by a man with a plane table, which is essentially a drawing board mounted on a tripod, drawing the map as he observed the country. Control points were marked on the ground and plotted on his drawing sheet, and he was usually provided with suitable instruments for the measurement of lengths, directions and differences of elevation. Progress of one square mile per day was considered satisfactory. This plane table method is still used to a considerable extent in some places, but in Canada it has been largely superseded by the photogrammetric method. With the aid of aerial photographs the work can be done much more quickly, and much of it can be done in the office. Nevertheless there is still a great deal of work involved in identifying objects on the photographs and in transferring information from the photographs to the sheet of paper which will eventually be the map. The main difficulty arises from the fact that an aerial photograph is not a plan but a perspective view. We all know the classic example of perspective in the photograph taken looking along a railway. The size of the image depends on the distance to the object, and thus in an aerial photograph a feature on top of a high hill would appear larger than an equal feature at a lower elevation. Also, all photographs are not taken from the same height. In the course of the original photography, photographs are taken on roll film, at regular intervals of time, as the pilot tries to fly along a straight line at constant height. Since it is not possible for the airplane to maintain perfectly level flight, the scale of different pictures in the roll will be slightly different, the varying height of the airplane having the same effect as variations in the height of the ground. Heights are determined from a stereoscopic effect, or the fusing of two pictures taken from different viewpoints. The principle is the same as that of the old-fashioned parlour stereoscope, or of the modern view-master. The time interval between photo exposures is so related to the speed of the plane that the pictures overlap by about sixty per cent. Thus each point on the ground appears on at least two pictures. The method of transferring information from the photographs to the map sheet is very complicated, but many plotting instruments have been designed to aid in this process, and with their help

accurate horizontal and vertical information can be obtained from pairs of overlapping photographs. With satisfactory control and good photography these machines can be used to produce excellent topographic maps and, in many cases, precise engineering plans.

Much progress has been made in recent years in the mapping of Canada, but the job is still far from finished. The entire country is mapped at the scale of about eight miles to the inch, but many of these maps give no indication of heights above sea level, and cannot truly be called topographic maps. Considering contoured maps at a scale of four miles to the inch or larger, nearly four-fifths of the Canadian mainland is mapped, and a start is being made on mapping the arctic islands. The mapped portion of the mainland is not concentrated in either south or north, but covers about the same proportion of the regions north and south of the 60th parallel of latitude. Substantial progress is being made in this difficult but important operation, but it will be several years before adequate medium scale topographic maps are available for the whole of Canada.

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DR. FRITZ MÜLLER

15: Ice

The ice in the Arctic is increasing, especially around Alaska. Will there be another Ice Age? This authority says "most likely" – but don't pack up yet for to a glaciologist a thousand years are but a day.

Glaciology is the study of ice and snow in their multitude of appearances: ice and snow in the glaciers and snow fields of the far northern and far southern latitudes, ice and snow in the glaciers of the high mountains—and ice in the sea, in lakes, in rivers and in the permanently frozen ground of the Arctic and Antarctic. But glaciology also includes the study of the "dangerous" ice on the roads and on the wings of aircraft. It includes the study of the beautiful snow flakes in the air and the wintery snow cover on the ground and even the hailstones of a thunderstorm.

Glaciology today is one of those interdisciplinary sciences that draws on the knowledge of physics, crystallography, meteorology, geology and geography.

A brief look at the freshwater situation of the earth illustrates the importance of glaciological research. The quantity of freshwater stored up in the form of ice on the earth's surface today is estimated to be six million cubic miles, whereas the total volume of freshwater in all lakes, rivers and ground water basins together with that circulating in the atmosphere amounts to less than a quarter of a million cubic miles.

By tradition, and historically, glaciology is primarily concerned with the ice in glaciers. Glaciological research started some 150 years ago when Swiss geologists and English physicists took the first series of measurements on glaciers in the Alps. Based on this

work we know that in the last 100 years the ice reserve on earth has decreased by about one per cent—that is by the amount of the water contained in all freshwater lakes.

Today glaciers cover only ten per cent of the land surface on the earth. But in the Pleistocene ice age, that is in the geologically recent past, nearly one third of the land was covered by ice. The action of the ice is clearly engraved on that third of the earth's surface. Glaciers both help to create and enhance some of our most spectacular landscape. The beauty of the Himalayas, the Andes, the Rockies, of Greenland and the Antarctic would greatly diminish if the glaciers disappeared.

The melting of all the existing ice on the earth would lead to a rise of sea level of approximately 300 feet which would be disastrous for many thickly populated areas.

Currently some scientists are concerned that the increase of carbon dioxide in the atmosphere arising from industrial activity may cause a warming of the climate and a consequent melting of the ice masses. Actually it is far from certain that a warmer climate would result in a shrinkage of the main ice sheets. Most of the arctic and antarctic ice masses are now much colder than is necessary to maintain themselves. Probably their temperatures could rise several degrees without any drastic reaction. In fact, some glaciologists believe that a slight warming of the climate might cause the glaciers to expand by enabling the air masses to deposit more snow on them.

Glaciers are very sensitive and respond in many different ways to changes in climate. The glaciers record—in some respects even better than any man made instrument—the behaviour of the various meteorological elements. So by digging deep shafts in the ice caps and glaciers and studying the exposed layers of snow and ice, it is possible to determine hundreds of years of climatic history.

Industrialization brought a considerable change in the geochemical composition of the atmosphere. There has been a marked increase in the amount of sulphur and rhodium 102 and, more recently, of radio-active particles. The snow, firn and ice layers of arctic glaciers are well-preserved beds of petrified precipitation containing these elements from hundreds and thousands of years ago. Analysis of their chemical composition shows up these changes.

Recently it has been suggested that the huge ice masses of the Arctic and Antarctic should be used for the disposal of the waste material from atomic energy production. Neither rock caves nor the floor of the ocean provides a really safe storage place whereas the natural accumulation of snow on the high polar glaciers would in fact bury these radioactive materials deeper and deeper every year. As no intercrystalline water circulates in the ice of the polar type of glacier there would be no seepage.

The glaciers of the temperate latitudes, such as those in the Alps and in the Rocky Mountains, have long been known as important water sources for hydro-power stations. In many areas the melt-water supply is at a maximum during the dry season, consequently smaller storage basins are required, thus saving enormous amounts of money. In spite of the development of thermo-nuclear power there continues to be an increasing need for hydro-electric power production, particularly in the underdeveloped countries bordering the Himalayas and the Andes.

"Will there be another Ice Age?" It is impossible to give a direct answer to this popular question that is asked so often. The main trend of the arctic and temperate glaciers is a retreat. However, there are a few advancing ones in most areas, and of the glaciers along the Pacific coast of Alaska almost half are advancing. Preliminary results from International Geophysical Year research in the Antarctic seem to indicate that this largest ice sheet is increasing. There is no reason to believe that we are on the verge of a new ice age. However, glaciological history shows several ice ages in the past, and therefore it is possible, indeed likely, that such a change may occur again.

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16: Permafrost

If you dig a hole in the Arctic, summer or winter, you'll likely come thud against a layer of ice and soil. That's permafrost. It presents a nice challenge to builders who don't want their schools or houses to stand leeringly drunk when their "foundation" turns to sog. It is one arctic barrier the experts are surmounting.

Permafrost is an unusual word but it is one well known in the North. Permafrost—the word itself—seems to have been first used by Dr. Siemon Muller in a special brochure he prepared during the war for American defence authorities which dealt with northern construction. But the condition of the ground that the word describes is one of the oldest of all the features of the North, permafrost having been in existence for possibly a million years.

Those who live in the North know that if you dig a hole through the muskeg, or in soil where it is exposed, you will very quickly come up against a hard impenetrable layer, even at the end of summer. If you look at this hard layer, you will see that it consists of ice and soil (or ice and muskeg) showing that the ground is solidly frozen even at this shallow depth. It is to this perennially frozen condition of the ground that we give the name permafrost.

Let me try to explain the cause of permafrost before we review its effect on northern development. My office is in Ottawa. If I go outside this building and drill a hole in the ground and then measure the temperature of the ground, we will find a regular sort of pattern. Near the surface, the ground temperature will be close to that of the air above. On this lovely summer day it might be as

high as 60°F. As we go deeper, however, the temperature will drop until at a depth of about twenty feet it becomes steady at about 48°F. This steady temperature will not vary at all throughout the year. When we look up the records we shall find that this steady temperature of about 48°F is just a little higher than the average air temperature throughout the year here in Ottawa.

This is really what you would expect when you come to think about it. And so we find the same thing as a feature of all ground temperatures—that the steady temperature of the ground, below surface influences, is approximately the same as the average air temperature at any location. Now let us travel north. The average annual air temperature at Edmonton is about 37°F, at Fort Smith it is 26°F, and at Yellowknife it is 22°F. Accordingly we would expect that somewhere near to Fort Smith the steady ground temperature is below the freezing point. This is another way of saying that we should find permafrost—and we do, just the beginning of it, on what we call its southern boundary. This is really not a very good name since boundary suggests a definite line, and permafrost doesn't start as suddenly as that. There is, rather, a fringe area in which the start of permafrost may be expected.

This border zone extends all the way across Canada. In the Yukon it starts near Whitehorse, away to the north because of the warming influence of the Pacific Ocean on climate. It swings quickly south to cross the Slave River north of Fort Smith, affecting the new northern town of Thompson in Manitoba, further to the east, reaching its southern limit on the shores of James Bay in Ontario. In Quebec it swings north again, crossing the area of the great new iron mines to reach the Labrador coast just north of Goose Bay.

All of Canada to the north is underlain by ground that always remains frozen to a depth of just a few feet in the border zone but to depths of many hundreds of feet in the far North. The depth increases roughly about 100 feet for each degree fahrenheit drop in average air temperature. At Resolute, for example, on Cornwallis Island in the Queen Elizabeth archipelago, the ground has been shown to be frozen to a depth of at least 1,300 feet. I am writing about a vast area, actually about half the total land area of Canada. Only one other country, the U.S.S.R. has anything like this area of permafrost, and it has rather more than we have.

All of what we call the North is therefore underlain by this strange phenomenon that we call permafrost.

We must next ask why this strange condition of the ground is important in the development of the North. If the ground consists of solid rock, right up to the surface, as it does in so much of the North, it really makes little difference whether it is frozen or not. It is still solid rock, excellent for foundations, but requiring drilling and blasting for its excavation and removal. In the same way, if the ground consists of well drained dry sand and gravel, its temperature—whether above or below freezing—does not matter very much. Such ground still remains one of the best of foundation conditions and it provides some of the most useful of all building material by the simple process of just digging it out.

If, however, the ground near the surface consists of clay or silt that is naturally moist or wet, then the situation is quite different. It is here that almost all the troubles with permafrost arise. For the water naturally contained in the soil will be frozen. If the water always stayed frozen, we would have no problem, since the frozen soil-water mixture would always be as hard as a rock. It is when this water in the soil thaws out that problems are created.

In the first place, the top few inches, rarely more than a foot or two, will thaw out naturally at the end of the summer and then freeze again as soon as summer days are over. Scientists call this the "active layer". All who have had to do any walking in the far North over muskeg or similar country know how terribly difficult walking is in August and early September because of this water soaked surface layer.

Some of the early explorers of the North did notice this frozen condition of the ground even in high summer. Alexander MacKenzie, to mention just one of the greatest of the pioneers, observed it and recorded it in his note books. And early scientists studied it. One group made an interesting report upon "permanently frozen ground" (as they called it) to the Royal Geographical Society in England as early as 1837. But nobody bothered very much about it until the years of the 1939-1945 world war. For it was only then that we began to build anything more than the simplest of houses throughout the North. It is when major building is carried out in the North that troubles can

develop if the ground conditions at the building site consist of frozen clay or silt.

It is our job, in the Building Research Division of the National Research Council, to assist the builders of Canada with their special problems. And since the existence of perennially frozen clay and silt provides the most serious of all the problems of the North, it is natural that the Division should have given special attention to it. (The name permafrost is widely but really quite incorrectly applied just to perennially frozen clay and silt, even though the word really means the frozen condition of any ground. Forgive me if I myself use it in this incorrect way.)

As a centre for our northern research work, we established over ten years ago a special permafrost research laboratory (with the kind co-operation of Imperial Oil Ltd.) at Norman Wells. Here we have facilities for analysing samples of frozen soil brought in from the field.

Now that a much larger general research laboratory has been built at Inuvik, we may find that our small installation at Norman Wells has served its purpose. It was, however, a pioneer in its field and much useful work has been carried out there.

The whole secret of successful building on permafrost is to know exactly what your site conditions are. If you know what you have to build on, then you can design your building, your road, your airfield accordingly and include the necessary precautionary measures.

All too often buildings in the North have to be erected, roads and landing strips constructed at sites that consist of nothing but frozen clay or silt with its muskeg cover. Since this material in its frozen state is hard and solid, clearly the job of the designer is to try to keep it frozen. This simple idea is the key to all successful design over permafrost. I could tell about some really horrible failures of buildings, and of roads, that were not designed on this simple principle with the result that the permafrost beneath them thawed out and failed to give proper support. In the North, "drunken buildings" are those that have settled unevenly because of melting permafrost beneath them.

Let us think instead of the many fine buildings now to be found in the North—that have been well designed and are performing well. One way in which the designer achieves this good

result is by separating the buildings from the ground, on wooden piles or special trestles, so that the heat from the buildings cannot reach the ground to thaw out the permafrost. In the same way, muskeg is preserved and not disturbed for the building of roads and airfields, being covered usually with brush on which is piled the sand and gravel to form the roadway base.

These are engineering matters but they depend upon an accurate knowledge of the ground conditions at the building site. Canadian scientists, engineers and contractors have made notable contributions to our knowledge of permafrost and how to deal with it. There is still a lot about it that we have to learn (especially about some of its more scientific aspects). But we already know enough to ensure successful building in the North, when economics or national policy require such building. And we are already exchanging information fruitfully with others interested in permafrost, including notably scientists and engineers in the U.S.S.R. They face similar problems in some parts of their North; they too have experienced failures and learned sound methods of design and construction. International co-operation in this sphere too can be only profitable . . . but that is another story.

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DR. M. J. DUNBAR AND W. B. BAILEY

17: Circulation of the Arctic Ocean

A dam across Bering Strait to warm up the Arctic is something nice to think about for the future; but "for the moment, landing on the moon is probably more fun and less trouble".

Little attention was paid to the Arctic from the oceanographic point of view until after the second world war. In the early 1950's, Canadian and United States oceanographers began studies of the Beaufort Sea and the western part of the Arctic Archipelago. Results of their efforts were helpful in the supporting role of getting the United States Navy nuclear submarine, *Nautilus,* through the Arctic Ocean. At the same time, Russian and American oceanographers were making observations through the ice in the central part of the Arctic Ocean. The Russians were resuming studies starting in 1941, but the United States scientists were starting fresh.

During this series of ice landings, the Russian scientists discovered a submerged mountain extending from Greenland to Russia and cutting right across the Pole. The United States scientists who were working in the western part of the Arctic Ocean deduced the presence of a ridge by the temperature and salinity characteristics of the deep water.

In 1954, Canada's oceanographic effort in the Arctic came into its own with the availability of *HMCS Labrador* for oceanographic work. In that year, while traversing the North West Passage, oceanographic observations were taken which permitted

a direct comparison with the waters found in Baffin Bay, the Arctic Archipelago and the Beaufort Sea. In the years following, oceanographers in *Labrador* made very detailed studies of many previously unknown areas such as Foxe Basin and Prince Regent Inlet. *Labrador,* now a Canadian Coast Guard vessel, carries oceanographers with her each summer and now nearly all of the eastern part of the Arctic Archipelago has been covered.

Beginning in 1959, oceanographers with the Polar Continental Shelf project took oceanographic observations out from the shores of the Arctic Archipelago into the Arctic Ocean. By working through the ice and being transported from place to place by aircraft, noteworthy contributions are being made by these dedicated men. In the past dozen or so years, our knowledge of Canadian arctic waters has increased tremendously.

At present, we are still gathering general data to make our studies more comprehensive. Progress is slow, simply because the weather and the ice are not the most co-operative. However, within the next few years, we may expect even greater advances as the full analysis of the data nears completion, and makes its way into the scientific literature. But perhaps we should go back a bit and describe the Arctic Ocean as we found it, so to speak.

Imagine a shallow bowl, two and a half miles deep and eighteen hundred miles wide, with a ridge along the bottom almost dividing it in two, and you have something like the shape of the central basin of the Arctic Ocean. This is the water-filled depression at the top of the world, surrounded by Canada, Alaska, Siberia and certain islands such as Novaya Zemlya and Spitsbergen, and Greenland. Add to this such peripheral seas as the Greenland and Norwegian Seas north of Iceland and northern Norway, the Barents Sea, Baffin Bay and the waters between the Queen Elizabeth Islands in our own Arctic, and you have the whole Arctic Ocean system. Forming the southern boundary on the Atlantic side is a submarine ridge between Baffin Island and Greenland, between Greenland and Iceland and between Iceland and Scotland; the top of this ridge is only about 600 metres (2,000 feet) beneath the sea surface.

This circulatory system contains at least five different kinds of sea water, with different temperatures, salinities (that is to say, salt content) and densities. In the Central Basin, or "Arctic Sea",

there are three layers of water: first about 600 feet of very cold water and with a little less salt than the Atlantic Water. This is the Arctic Water proper, formed in the Arctic Sea itself by the mixture of Atlantic Water, melt water from ice, and the runoff from the land. The land runoff amounts to about 4,000 cubic kilometres per year, which sounds like a lot of water but is very much less than the volumes of the flow of the ocean current involved.

The ice on the surface of the Arctic Sea, which may be anywhere from a few inches to about forty feet thick, plays quite an interesting part in the formation of this upper water. When salt water freezes, the salt in it is concentrated in little pockets of brine, and as the cooling process continues these pockets steadily freeze at the top and thaw out ice at the bottom, because of their high salinity, so that in the course of a winter the salt has migrated downward through the ice and is ultimately released into the sea water below. This very saline water then sinks down out of the local picture, so that there is a net loss of salt to the upper water layer. This is the reason why sea ice, so long as it is a year old or older, is comparatively fresh and can be melted and used as a fresh water supply. When this old ice melts, of course, it lowers the salt content of the sea around it.

The second layer in the central Arctic Sea is a layer of Atlantic Water over 2,000 feet thick. This has come north from the North Atlantic Drift, the continuation of the Gulf Stream, and meets the cold surface Arctic Water west of Spitsbergen. Although the Atlantic Water is considerably warmer than the Arctic Water, it is also more saline, and therefore sinks beneath the upper Arctic layer. At this point the Atlantic Water is about three or four degrees centigrade (between 37° and 39°F.), whereas the Arctic Water is usually below 32°F. The difference in salinity is a matter of two or three parts per thousand, the Atlantic Water being about thirty-five parts per thousand.

The third water mass is the Arctic Deep Water, which occupies the two basins on either side of the ridge (Lomonosov Ridge) which divides the basin in two. There are in reality two different water types here, because the two basins have slightly different water in them. Both lie below the Atlantic layer, both are cold, below 32°F., and neither concerns us here any more, because

they move only very slowly indeed; they form a sort of floor for the two upper layers.

The Atlantic Water layer circulates around the basin in a sedate counterclockwise manner, and takes between three and four years to complete one turn. In doing so it has lost much of its heat and its substance to the upper layer, but the remnant is still easily distinguishable from the Arctic Water proper.

There is another inflow of water into the Arctic Sea. The northward flowing current through Bering Strait, between Alaska and Siberia, contributes cool North Pacific (Bering Sea) Water at the average rate of about one million cubic metres per second, if that figure means anything to you, or about thirty-one and a half thousand cubic kilometres per year. This is only about one quarter or one fifth of the Atlantic Water inflow on the other side, according to present estimates, but it is still a handsome current. This Bering Sea Water is cool, close to 32°F, and it continues northward across the Arctic Sea; some of it keeps right on going, flowing out at the Atlantic side, but most of it is deflected to the right and forms a clockwise gyral or circle in the Beaufort Sea, north of Alaska and the Mackenzie District, and along the outer coasts of the Canadian Arctic Islands.

The bulk of the upper Arctic Water flows from the west Siberian shelf across the pole, then southward and south-westward towards the larger of the two exits from the Arctic Sea, east of North Greenland. Here it concentrates into the East Greenland Current, some of which disappears eastward into the Greenland and Norwegian Seas, the remainder continuing south between Greenland and Iceland. Off southeast Greenland this cold water meets warm Atlantic Water, and the two together, more or less mixed, flow around the southern tip of Greenland to form the West Greenland Current. The West Greenland Current is subarctic, not arctic; it is a mixed current and is rich in life, including that prince of fishes, the Atlantic cod.

There is another outlet from the Arctic Sea, through the channels of the Canadian Arctic Islands into Baffin Bay and Hudson Strait. This cold outflow, together with West Greenland Water, helps to form the great Labrador Current, which has a rate of flow five or six times the rate of the Bering Strait Current.

The climate of the northern part of the world is to some extent controlled by this arctic pattern of ocean circulation; the spread of land-ice southward, for instance, in ice ages, has been thought to have started at times when the Arctic Sea was open, not ice-covered, when the arctic atmosphere was in fact warmer and wetter than it is at present. With this sort of thing in mind, several Russian engineers have suggested at various times that if it were possible to close Bering Strait with a dam, and pump water across it or through it, the climate of the North would improve, or at least change. One objective in this scheme would be to remove the cold upper layer of Arctic Water and bring the Atlantic layer to the surface, with its enormous store of heat. One wonders very much, however, whether such an engineering feat is possible, or that it will ever be done. The largest pump so far operated efficiently would take no less than almost 700,000 *years* to pump this upper layer southward, and even if many such pumps were used, or if their output were greatly increased, at great cost, the time scale would be such that nature would keep on forming new Arctic Water as quickly as it was pumped off.

If a Bering Strait dam were built, and no pumping attempted at all, this would of course have the effect of stopping the inflow of a large amount of water; and this would in turn reduce the cold arctic outflow by approximately the same amount. This might be expected to have a significant warming effect upon the West Greenland Current and the Labrador Sea. After much approximate arithmetic, one comes to the reluctant conclusion that the maximum effect possible would be to raise the temperature of the Labrador Current by about half a degree centigrade. This is not insignificant, but it would not be worth bothering about for the time being. Bering Strait is 46 miles wide and 150 feet deep. A dam across it is something nice to think about for the future; for the moment, landing on the moon is probably more fun and less trouble.

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MISS MOIRA DUNBAR

18: The Nature of Sea Ice

"As restless as the sea itself," sea ice is; but they're getting its movements "taped" and have no intention of turning it back to the polar bears. It is all a part of our environment and the more we learn of it the more we learn of other things.

I once asked a woman in Skagway, Alaska, whether the fiord there ever froze. "Oh no" she said, "it's salt water, you know." As if that settled that. She was quite astonished when I told her that the salt would not prevent it from freezing. To anyone in eastern or northern Canada this will of course be no surprise, but not everyone may have stopped to consider what are the actual differences between sea ice and lake or river ice.

Well first of course there is the difference of temperature. Fresh water freezes at 32°F, whereas sea water does not freeze till it is around 28.6°F—the exact temperature varies according to how much salt there is in it. There is also another reason why ice forms less readily in salt water. When the surface of a body of water cools, the cooled water, which is heavier, sinks and is replaced by warmer water from below. This water in turn is cooled and sinks, and so it goes on until the temperature of maximum density is reached. Maximum density is also maximum weight, so after this point is reached the cooled surface water is lighter than the water below, it no longer sinks and mixing stops. In fresh water the temperature of maximum density is 39.2°F, and after the water mass has reached this point the cooled water remains on the surface, the rate of cooling increases, and ice quickly forms. In salt water, however, the temperature of

maximum density is lower than the freezing point, which means that the whole water mass has to cool to this temperature, (28.6°F) more than ten degrees lower than for fresh water before any ice can form. This is why ice always forms on lakes some time before it appears in the sea.

The physical and mechanical properties of sea ice are also different from fresh. It is for instance much less brittle and more elastic than fresh water ice, and when still fairly thin will bend quite considerably before it breaks. The salt does not actually freeze, but is distributed through the ice in little pockets of brine which gradually drain and leach out as the ice gets older, so that eventually, in about one to two years, it becomes almost fresh, and melt-water from surface puddles can be used for drinking. Ice over a year old is not only usually thicker than first-year or winter ice but it is also fresher and harder and altogether more formidable. It is known as polar ice.

The most characteristic feature of sea ice is perhaps movement. Around the coasts of course there is fast ice, so called because it is attached to the shore, and it may extend for many miles off the coast; in narrow or enclosed seas it may even cover the whole surface from shore to shore. But in the larger areas, such as the Arctic Ocean, Baffin Bay, and Hudson Bay, and in the seas where ice cover is less complete and less long-lived, such as the Gulf of St. Lawrence and the Baltic Sea, the ice is as restless as the sea itself, perpetually moving, breaking up and freezing together again, and following a surprisingly constant path in its wanderings under the influence of wind and water currents.

These drift paths have become fairly well known, especially in the Arctic Ocean, where they have been studied by means of drift expeditions for as long as ninety years. Up until the second world war such expeditions were almost all by ships, some of them frozen into the ice deliberately, some accidentally, and they were few and far between. The use of aircraft, however, made the arctic ice much more accessible and the tempo of research has increased greatly. Since 1937 scientific groups have dispensed with ships and set up camps right on the ice. The pioneers in this field were the Russians, who since 1950 have maintained a continuous series of ice-flow stations. As soon as one begins to drift out of the area they abandon it and set up

another at another point. The United States has also had several scientific stations on the arctic ice.

The result of all this movement is that the ice cover is never really continuous. Differential movement causes the ice floes to break and separate and then to crash together again, throwing up great ridges of broken ice which may be ten or twenty feet high. It is often a surprise to people to learn that there are always open leads and pools in the Arctic Ocean, even in winter, and that some of them are quite extensive. In summer, of course, the openings are rather more extensive, while in many areas of the marginal seas the ice either disappears altogether or becomes greatly reduced.

I am often asked why it is necessary to study sea ice. What good is it, runs the argument, why not just leave it to the polar bears and forget about it? The answer, to my mind, is simply that sea ice is part of the physical environment of our planet, and that it is only by learning to understand our environment that we can hope to make the best use of it. And this is true even if we do decide to leave the ice to the polar bears and live in more temperate climes, because the arctic ice affects not only the Arctic itself but also sea and weather conditions in other parts of the world. Furthermore, with increasing interest in the mineral and oil potential of the Canadian Arctic, it looks as though traffic in the arctic seas is going to increase rather than decrease.

The study of sea ice is actually a very young science. Fifteen years ago for instance, or even ten, the suggestion that it would be possible to forecast ice conditions was regarded by most experts in North America as ridiculous. And yet today the Canadian Meteorological Service provides ice forecasts on a routine basis, for the Gulf of St. Lawrence in winter and the arctic shipping routes in summer. These forecasts are made on the basis of daily or near daily reconnaissance flights by trained observers, combined with data on water temperature and currents and with weather forecasts. The reconnaissance flight tells the forecaster where the ice is, how much of it there is and what is its approximate age and thickness and size of floe. The factors he must forecast are the rate at which it is melting or growing, and the rate and direction in which it will move. The first is dependent on water and air temperatures, and the second on current and

wind. In both cases the meteorological factor is more significant than the oceanographic one; air temperature is more important than water temperature because it is more variable and will therefore have a more variable influence, and wind is more important than current because it is the prime agent causing the ice to drift. In the final analysis, therefore, the ice forecast is dependent on the weather forecast. The technique is still young and there is room for improvement, but it is nevertheless proving very successful. In the Gulf of St. Lawrence, as a result of the reconnaissance and forecast programme and of the provision of icebreaker support, shipping now continues throughout the winter. In the winter of 1962-63, a total of 488 vessels entered the gulf, of which 189 were given icebreaker escort, compared with practically none a short five years ago.

As an important by-product of the reconnaissance programme there is being accumulated a backlog of statistical data on which to base climatic means. Just as in the case of weather, it is necessary to have many years of recorded observations before mean or typical conditions can be established, and just as with the weather it is turning out that in spite of great variations from year to year there are basic patterns which repeat themselves more or less predictably. And while I am on this subject of repeated patterns I should perhaps say a word about climatic change. It is well established that throughout historic times there have been several long-term fluctuations of climate, and that in the last fifty years or so we have seen a considerable warming in the northern climate. Ice thicknesses measured in the Arctic Ocean have decreased, glaciers have shrunk, warm-water fish have moved northward, and so on. It has been suggested that this trend might continue and the arctic ice all melt, leaving an open polar sea and a Greenland that was truly green, while the extra water released by all this melting of ice would raise the sea level so much that all the coastal cities of the world would be flooded and low-lying areas, such as Florida, almost completely submerged. However this actually seems rather unlikely, at least for the present, and there are in fact indications that the peak of the warming period has already been passed.

I cannot close without mentioning the latest innovation, which brings us right into the space age, and that is the use of satellites

for ice reconnaissance. The *Tiros* family of meteorological satellites, whose chief function is to photograph cloud and transmit the pictures to a readout station by television, have been found to show ice rather well, as well as cloud, though it is often hard to tell which is which. In 1962, a programme of intensive photographic and visual reconnaissance was carried out to coincide with passes of *Tiros IV* over the Gulf of St. Lawrence. With the aid of the photographs and ice charts so obtained it is hoped to establish interpretation techniques for determining ice characteristics in the satellite pictures and for distinguishing between ice and cloud. Perhaps the mariner of the not so distant future may get his ice information directly from a satellite readout station within minutes of the actual observation.

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NORMAN G. GRAY

19: So Ships May Safely Sail

The Dominion Hydrographer says modestly it will be many decades before all our arctic waters have been surveyed. But the layman will stand in some awe at how much has already been done in an area we had believed a vast unknown.

Hydrography is the charting of navigable waters, generally for commerce and defence, of oceans, lakes, rivers and canals—wherever ships might travel. The southern part of Canada has waterways in abundance: the broad St. Lawrence and the Seaway, the Great Lakes, the Atlantic and Pacific coasts with their many islands and inlets. But the most extensive and most challenging of Canadian waters lie in the North: Hudson Bay, Foxe Basin, Gulf of Boothia, Beaufort Sea, Baffin Bay, Viscount Melville Sound, and many other straits, bays, and channels between the numerous islands that make up the huge Arctic Archipelago. There are also large lakes and connecting waters, such as the Athabasca-Mackenzie Waterway including Great Slave Lake and Great Bear Lake which make up an important transportation system.

Yet for more than three and a half centuries from 1576 to the second world war, the only hydrographic information available on most of the navigable waters of the North was contained in the yellowed pages left by early explorers, who had dared the North in their quest for a northwest passage to China, and by those who took part in the search for the ill-fated Franklin Expedition. This information was recorded in three volumes published by the British Admiralty under the name of the "Arctic

Pilot—A Guide for Seafarers", and some small-scale charts of large areas, supplemented by plans for harbours and anchorages, made by the crews of vessels of these early expeditions.

Until 1883, all hydrographic surveying in and around Canada had been done by the Royal Navy. That year the Canadian Government recognized its responsibility for hydrography by starting a survey of the Great Lakes. In 1904 the Canadian Hydrographic Service was established—its task being the charting of all Canadian navigable waters.

The first ship to be built especially for hydrographic surveys in the North was *C.H.S. Acadia,* which was delivered in 1913 and is still doing service on the east coast. The newest and perhaps the world's most modern survey vessel, *C.H.S. Baffin,* has carried out hydrographic surveys in the Arctic annually since 1958.

The establishment and supply of joint Canadian-United States weather stations and Distant Early Warning radar stations brought the United States Navy and the United States Coast Guard task forces into Canadian arctic waters from 1942 to 1959, and hydrographers of both nations assigned to these ships have added to the knowledge of many of our northern waterways.

Because of the increasing demand for modern hydrographic charts and sailing directions and a shortage of survey vessels specially designed for northern operations, the Hydrographic Service has assigned teams of hydrographers to icebreakers and northern supply ships of the Canadian Coast Guard fleet operated by the Department of Transport, and to a ship of the Royal Canadian Navy. Sealing ships have been chartered and used annually since 1950 on hydrographic surveys required as a result of mineral exploration and development in the Hudson Strait—Hudson Bay areas.

In 1961, for example, hydrography in the North was carried out by our survey ship *Baffin,* two chartered sealing ships, and by hydrographers aboard four Department of Transport icebreakers and a Royal Canadian Mounted Police boat.

Life aboard chartered sealers in arctic waters was never too comfortable for survey staff as these men were an addition to the normal ship's complement. Hazards from ice, weather, the handling of small boats and rigours of extremely rough terrain were normally daily occurrences. Ice in northern areas, particularly

in the early part of the season, greatly hampered operations. Difficulties of passage alone have been recorded every year; in one instance ten days travelling 200 miles through ice in Frobisher Bay; in 1956, at the entrance to Hudson Strait, the ship was caught for thirty-two days in the ice and covered only about 150 miles towards her destination. One of the chartered sealers was instrumental in salvaging a commercial vessel that had grounded on an uncharted shoal near the head of the Bay. Fortunately our survey vessel was in the vicinity and was able to assist in freeing the grounded ship on the next tide, and to guide her to the only suitable location so that temporary repairs could be made, thus enabling the ship to return under her own power to her home port. It was only by using the specialized knowledge of our survey officers on the tidal conditions and foreshore drying areas that this could be carried out successfully. On all of these occasions these hardy little sealers sustained little or no serious damage in these adventures.

Not all of the problems concerned ice. While charting the icefree waters of James Bay in August 1961, another sealer used by this Service struck an uncharted rock pinnacle and became a total loss. Although the ship did not sink immediately, eventually all hands had to take to the boats and spent an uncomfortable night on a small island in the vicinity before help arrived.

In the eighty years that the Canadian Hydrographic Service has been engaged in charting the navigable waters of Canada, we have experienced groundings, collisions and other accidents, but considering the type of work in which we are engaged, these have been relatively few. Total losses have been only two vessels, both in James Bay; one the sealer—in 1961, and the other an auxiliary three-masted schooner wintering at Rupert River in 1913, driven ashore by ice during the spring break-up. Loss of life as a result of hydrographic operations fortunately has been extremely light; to the best of my knowledge, since about 1900, there have been five fatalities, all from drownings.

Why is all this done? Quite simply – because our nation cannot afford to neglect its northern areas. Apart from considerations of commerce, national defence, and sovereignty, there are indications that mineral wealth may be hidden in the rocks and sediments of the arctic shores and islands, and under the sea. Safe navigation

is impossible without accurate and comprehensive hydrographic charts, delineating the coastline, dangerous and safe depths, clearing lines and aids to navigation, as well as tidal and ice information.

There are, however, vast areas of the Arctic where hydrographic surveys by conventional methods are impossible as the sea and channels are permanently covered by ice. Although these may be accessible only to the heaviest icebreakers for a few weeks of the year, it is still essential that we know the depths available. This information is invaluable to geologists and geophysicists in their search for minerals and other geological deposits of economic interest. It seems likely that, once found, the only way that these resources can be exploited will be by large cargo or tanker submarines. Consequently it is essential that they be provided with adequate charts of their routes.

Turning a little farther south, but still very much north for most of us, hydrographers in 1961 completed a reconnaissance of the Athabasca and Slave Rivers, and two books of river charts were published in 1962, covering the route from Waterways, which is the end of the rail line from Edmonton, to Great Slave Lake. During the next few years this series of charts will be extended down the Mackenzie River to Tuktoyaktuk and the sea.

In the Arctic Ocean itself, much progress has been made in recent years by the preparation of a provisional series of small scale charts showing the routes which are used regularly. A start has been made to provide large-scale coastal charts, which are so important to orderly economic development, and many of the more important harbors are covered by modern large-scale plans.

In 1956, a small group of specialists began to study all the reports and records of previous expeditions to the Arctic, together with thousands of aerial photographs taken since the last war. From this collection of information they produced the "Pilot of Arctic Canada", a work in three volumes, which contains the only modern sailing directions for our northern waters as well as a wealth of other details—historical, geographical, and even ethnographical. The "Pilot" is regularly updated by annual supplements as new information becomes available.

Although much progress has been made in recent years in the hydrography of the North, it will be many decades before all of our arctic waters have been surveyed. New ships are either being

built or planned, and new methods are being devised to assist the hydrographer in his work, thus promoting the economic development of the Arctic in which adequate charts must play an important role.

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DR. IAN MCLAREN

20: Marine Life in Arctic Waters

There aren't so many species as elsewhere but those that are there are plentiful. It is "the task and pleasure" of marine biologists to find why this is, and this article opens for the layman something of the wonders and excitement of man's tilt with the unknown.

The Arctic is commonly thought of as being full of unknowns, but in fact the northernmost seas are surprisingly well known in one important respect. Partly because the great fisheries of Europe and North America are carried out on the fringes of arctic seas, and partly because most northern exploration has been water-borne, and partly because of the collecting zeal of the northern Europeans in particular, we have a comparatively complete listing of the *kinds* of life to be found in arctic seas. I think it is safe to say that we are more likely to turn up new species of animals off our east coast than in our arctic waters. However, man cannot claim too much credit for this state of our knowledge, for the simple fact is that there are many fewer kinds of life to be found in these cold, northern waters. The business of cataloguing life in tropical seas will be a never-ending one by comparison.

It is probably significant that the modern theory of evolution was born over 100 years ago of the tropical experiences of Charles Darwin and Alfred Russell Wallace. It was easier to think of each animal and plant in its foreordained place in nature until biologists were shocked into thinking anew by the seeming excesses produced by the Creator in the tropics. It might be thought therefore that the Arctic would be a rather boring place for the enthusiastic marine biologist. I hope to tell you how this very lack of diversity

of life is part of the great fascination and importance of marine biology in arctic seas.

The Arctic is a very practical place to discover generalities about nature, and particularly to test ideas about the interrelations of organisms, and this is so *because* of the simplicity of the web of life in the Arctic. This has nicely served the ambitions of numerous students from our universities, anxious to get answers in a hurry, and has allowed small, even one-man expeditions, to make important contributions.

Perhaps I can best make a brief survey of arctic marine life by considering this question of why there are so few kinds of plants and animals in arctic seas. It must be understood that the total amount of living matter may exceed that in tropical seas, so to answer the question simply by saying that things are too tough for many kinds of organisms is not enough. A moment's thought will show that life might be just as tough for a million marine animals whether these are divided up into ten or a hundred species. It is worth noting that the violent fluctuations in numbers from year to year which are so familiar among arctic populations—especially on land, where foxes and lemmings are famous examples—are sometimes cited as evidence of the "harshness" of the Arctic. Actually, it can be shown that the cause of such fluctuations is more likely connected with the fact that each such species eats only a limited variety of food and is in its turn eaten by so few predators. Such year-to-year changes are not as noteworthy in the sea, but we are still left with the problems of why there should be so little variety in arctic marine life.

We are all aware that the earth has, geologically speaking, only recently come out of a truly overwhelming ice age. Just some 11,000 years ago in southern Canada, and much more recently over the arctic land mass, there was nothing but lifeless ice. It is not certain to what extent the seas were spared this catastrophe, and recent theories suggest that the central Arctic Ocean might have been more ice-free than at present. However, it is certain that arctic seas have seen much warmer times and much more diverse faunas and floras than at present, although at some of these "lush" times the geographical pole was not near its present position. Ever since the theory of evolution was formulated, biologists have wondered if the great tropical diversity is due mostly to the long

history of climatic stability, and if perhaps in the Arctic a comparably diverse fauna and flora have not had *time* to evolve since the termination of comparatively recent mass destruction by ice. Actually, the present arctic marine faunas were evolving long before the great advances of the ice sheets, which began some million-odd years ago. For example, the ice-loving ringed seal had close relatives some ten or twelve million years ago and present-day northern shellfish are known from that time. These northern marine faunas were forced south during colder periods, but extinction may have been far greater among the warm-adapted faunas of temperate regions. It seems easy to argue that, unless evolution proceeds much more slowly at high latitudes, there has been quite enough time for a more diverse, arctic-adapted fauna and flora to evolve.

Can it really be then that there is in some way not too much *opportunity* for more kinds of animals and plants? Opportunity in this sense has a special term in ecology. It is called the "ecological niche". For example, trees are prevented from colonising the land because of forbidding permafrost a few inches below the surface, and we are not surprised at the lack of birds which must nest or feed in trees. In the seas, there are about as many species living on uniform mud bottoms in the Arctic as in the tropics. But coral reefs are kept from forming in high latitudes by certain absolute physical and chemical restrictions when light is absent or temperatures low. Thereby the complex and colorful communities of animals associated with tropical reefs have no counterpart in the Arctic. One almost imagines he can picture the niches which are missing in the Arctic in these cases, but it is much more difficult to see why animals in seemingly uniform open waters should be restricted in the same way.

All seas are inhabited by tiny forms of life that float about more or less at the mercy of the currents. These plants and animals are called the "plankton", and this plankton is certainly much less diverse in the Arctic. For example, off Bermuda, we might catch about eighty species of one kind of plankton, the tiny, shrimp-like copepods for a year's effort, and off New England, perhaps fifty species. In northern Foxe Basin, we would turn up some ten species for our troubles. And all this is in the light of the fact that the total weight of copepods and the overall numbers of

individuals is greatest in northern seas; it is just for some reason divided up differently.

The explanation for the small number of copepod species, and so on through all other levels of existence in the sea, seems to be bound up with one inescapable feature of the Arctic—and that is its very marked seasonal cycle. If we were to take an icebreaker into the consolidated pack at the end of winter and clear a neat little space for sampling, we would raise a rather poor selection of plankton in our net. We would find small populations of plant-eating animals, living on body-fat accumulated the previous summer, and even fewer of the animal-eating forms, preying on the few remaining plant eaters. The plants upon which ultimately all other open-water life depends would be almost absent; however, the potential would be there. We might sense this potential by chance as our icebreaker turned over an ice floe, to reveal a brownish or greenish scum on the underside. A microscope would reveal this to be myriads of tiny plant cells, some quite beautiful in form and colour, such as we would expect to find in the plankton later in the season. We would find also that the water under the ice was filled with the nutrient salts which plants need to grow, and deduce that the plants were flourishing on the underside of the ice because they were "starved", so to speak, for light, which barely penetrates the ice from the late-winter sky. In a few short weeks after our passage through the ice, the waxing of the sun and the wasting of the ice would let through enough light, and our nets would become clogged with millions of tiny plant cells.

Unfortunately this plenitude is short-lived. Off our east coast there is an equally great flourishing of plant life at the end of winter, but production may also occur through until late fall. In the tropics there is less seasonality again, and a sustained production of plants at all times of year. In the Arctic, everything is compressed into a few short weeks, after which the low sun and finally the reappearance of ice, cut off the production of plants.

It is this greatly restricted season of plant production which is the true "harshness" of arctic waters, and is ultimately responsible for the slow growth throughout the web of life. Mere cold is somewhat irrelevant, for an arctic animal may be adapted to low temperatures so that it grows just as fast as a southern relative, provided food is sustained. Arctic animals are reduced most of the

The Animals, Plants and Birds

Ledges on the granite cliffs on Digges Island, Hudson Bay, serve as high rise dwellings for thick billed murres. Leslie Tuck writes of these birds in Chapter 7.

When muskoxen think they are being attacked, they form their version of the old British square, heads out. These fellows on Ellesmere Island were photographed "on the loose", not in captivity. Dr. Tener describes them in Chapter 5.

An arctic wolf caught feeding on the remains of a muskox
near Eureka, Ellesmere Island.

This lone caribou on Baffin Island circled right around the field party, then went on its way. Dr. Banfield writes of caribou in Chapter 6.

The caribou roam alone and in groups large and small.

31

Mountain avens soften the arctic tundra in July and August, near Mould Bay, Prince Patrick Island. Dr. Porsild writes of plants in the Arctic in Chapter 9.

Rarin' to go, or to eat—the husky dog is still the Eskimo's main transport.

33

34

33 An oriole would not call the rocky shore of Ellesmere Island a "nest" but to the Arctic Tern, home is where your eggs are.

34 The ringed seal sometimes weighs as much as 120 pounds and can be four feet long.

year to picking up mere scraps from the great feast of spring. Even tiny planktonic animals less than one tenth of an inch long take a full year to complete their life cycles, producing their young only when food is abundant in spring. Some, indeed, take two years.

Ever since Darwin, students of evolution have amply demonstrated the tautology that the winners in the struggle to divide up the resources of the environment are those forms which change to become more successful in using these resources to promote their own kind. Sometimes organisms evolve to fill completely new niches in the natural world, but more often a new form makes more efficient use of something already being used, and thus forces other forms to specialize on some smaller portion of the available resources. Sometimes this leads to extinction, for there is always the danger that a specialized form will not always have its small, special, and necessary resource. In this way, there appears to be a real limit in the extent to which the environment may be divided up into niches for living things.

Now it will be clear perhaps why there are so few species—or if you like so few niches—for marine life in the Arctic. It is not possible to subdivide resources at times when they are simply not there; a copepod, for example, which might become proficient at using a certain kind of plant which occurs in late fall in southern waters, could hardly be expected to thrive in late fall in the Arctic when there are virtually no plant cells at all! Nevertheless, we may expect that the few species that we *do* find in the Arctic will show all the interactions among themselves and with their environments which occur in a vastly more complicated way in southern waters. Unravelling these interactions will be the task and the pleasure of arctic marine biologists for years to come, and will lead to a better understanding of nature and a wiser use of the resources of the seas by man in all parts of the globe.

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D. C. ARCHIBALD

21: Balloons Over the Arctic

The weather over Canada is dominated to a large extent by outbreaks of arctic air. So the weatherman has observation posts up there, balloons and all. One of the posts is nuclear-powered.

Suppose I invited you to accompany me on a trip to the Canadian Arctic. Doubtless, a few of the questions which you would immediately ask would be: what type of weather might we expect, what is the temperature, will we see much snow and ice, what clothes should we wear, will we see any vegetation, will aircraft be able to fly in and out of the Arctic regularly?

To answer these questions and many others and to explore the unknown in meteorology, a series of Arctic Weather Observatories were established at strategic points. We know that the weather over Canada and a large part of North America is dominated to a large extent by outbreaks of arctic air. Therefore, weather observations from the arctic regions form an essential part of the circulation picture of the atmosphere in the northern hemisphere.

It is true that expeditions to the Canadian Arctic have taken place at intervals over the past 300 years. Although only surface meteorological observations had been recorded for brief intervals, even those depended upon the route and duration of such expeditions.

To extend the frontiers of meteorological knowledge as well as to provide bases for other scientific disciplines, it was decided to establish meteorological observatories in the Canadian Arctic Archipelago. The costs of these installations were equitably shared

between the Canadian Meteorological Branch and the United States Weather Bureau, as both countries derived great benefit from them.

In 1946 some early reconnaissance, both by icebreaker and aircraft, was carried out. It was determined that a central location in the Arctic could be reached by icebreaker where supplies could be unloaded and cached, for subsequent lifting by aircraft to the selected destinations. Altogether five sites were chosen in the Arctic Archipelago in the Queen Elizabeth Islands. It was necessary to use the natural advantages of an unfamiliar terrain which at first appeared quite forbidding. For example, aircraft landings had to be made on sea ice and at a time when weather conditions were most favourable. It was determined that the spring of the year had probably the best flying conditions for this type of operation. Therefore, it was a two year project to establish an observatory. First, the materials and supplies were landed during August at a central point, Resolute on Cornwallis Island, by cargo ships supported by icebreakers. The following year these were airlifted to their destinations. This meant that all buildings, mechanical equipment, fuel, food, meteorological supplies and sundry items, had to be packaged in sufficiently small units that they could be man-handled and loaded aboard an aircraft and conveniently unloaded at destination.

The site of an observatory must meet certain specifications. The surrounding terrain should preferably be such that there are no natural obstructions that project higher than three or four degrees above the horizon. The immediate area around the observation point should be sufficiently flat to permit representative meteorological observations as well as providing adequate space to release the upper air balloons. One essential, for ordinary living purposes, is an adequate supply of fresh water nearby. The site must also have the capability for the development of a land airstrip within two miles or less of the site of operations. For future planning purposes, sufficient relatively flat land in the immediate environs should be available for expanding building sites, should the necessity arise. The site must of necessity be on the coast of the island selected to permit initial aircraft landings on the sea ice. For a small installation and due to severe temperatures and general climatic conditions, it is not practicable to haul supplies more than the distance of approximately two miles. During each

initial observatory establishment, station personnel had to assist with erection of buildings, the installation of electric generators, electric wiring, the operation of tractor equipment, building of land airstrips, snow clearance from airstrips, hauling of water and fuel oil, erection of meteorological equipment, radio antennae masts and everything which is necessary for a self-sufficient operating isolated station.

We have been able to staff these observatories largely on a voluntary basis. This has the advantage of obtaining those who have adventuresome and self-reliant characteristics, plus emotional stability and good physical health.

Well, what do we do up there?

Every three hours synoptic meteorological surface observations are recorded and transmitted by radio. These cover such elements as extremes of temperature, wet and dry bulb temperatures for determining humidity and the dew-point, barometric pressure, precipitation, depth of snow on the ground, wind speed and direction as well as observations of general weather conditions and cloud heights. I should mention too a few of the supplementary observations taken, such as, measurements of the gradient of temperature at lower atmospheric levels, physical characteristics of snow, thickness of ice and its rate of formation, gradient of temperatures in the permanently frozen soil called permafrost, depth of thaw in the summer, measurements of chill factors by means of an instrument known as a frigorimeter, ozone and radiation measurements, measurements of tides.

The world's first isotope-powered automatic weather station was established in August of 1961 on the southern tip of Axel Heiberg Island supplementing the reporting network. This unattended station has since 1961 automatically transmitted every three hours, information on temperature, wind direction and speed and barometric pressure.

For the upper air, large balloons inflated with hydrogen are released twice daily carrying a small instrument which transmits to the ground information on temperature, barometric pressure and humidity up to a height of 100,000 feet. The balloon-carried instrument is tracked by a radiotheodolite and the course is plotted from which wind speeds and directions aloft at various levels are determined.

In this programme there is close and amiable co-operation between the Canadian Meteorological Branch and the United States Weather Bureau. At the observatories, half the staff are Canadians and half Americans with a Canadian in charge at all times, yet the spirit on these stations is one of concerted pioneering determination to carry out a difficult task.

This operation may be considered as one of the finest examples of international co-operation for scientific purposes.

We now know more about the high level atmospheric circulation in the Arctic, the existence of belts of intense winds, called the arctic stratospheric jet stream, which occurs in the winter with winds in excess of 200 knots. We believe that marked 'seasons' in the upper air climate occur, somewhat similar to climatic variations at the surface. We know that scheduled airline flights, in and out of the Arctic, can be made with great regularity. A commercial company has operated successful scheduled flights into Resolute since 1961. Moreover five major airlines 'over-fly' the Arctic in the vicinity of the weather observatories.

The observatories have provided limited facilities and support bases of operation for other scientific disciplines, such as geologists, entomologists, archaeologists, communications experts, and other activities of the Department of Mines and Technical Surveys.

The central observatory was established at Resolute by water transport. This location is approximately 1700 miles almost directly north of Winnipeg, Manitoba. Other observatories, at Eureka, Isachsen, Mould Bay and Alert, which is only 450 miles from the Pole, have been established by air transport.

Perhaps you wonder if there are hazards—yes there are. One of our boys wrestled with a polar bear! Result—he was presented with the pelt as his trophy.

D. C. ARCHIBALD, *Chief, Basic Weather Division, Meteorological Branch, Department of Transport, Toronto. Born Sackville, N.B., 1906. Attended universities of Manitoba, and Princeton. Covered most of northern Canada, establishing weather stations and carrying out research, 1934 on. Fellow, Arctic Institute of North America.*

DR. B. W. CURRIE

22: The Northern Lights

Have you ever heard *the Northern Lights? Don't scoff too quickly if someone says they have – for maybe they have! And do you know a color film photograph of them will capture more color than your eye would have seen? Yet here's a scientist big enough to admit the aurora is still pretty much a mystery.*

All of you, who take even only an occasional look at our night skies, will have noticed the lack of northern-light displays during the past two years. Speaking more generally, I should say "lack of auroral displays", because this has happened everywhere—over Alaska and Scandinavia and the U.S.S.R. as well as Canada; over the Southern Hemisphere as well as the Northern Hemisphere.

Back in 1957 and 1958 when the International Geophysical Year was in progress, and in 1959, auroral displays were marvellous. In their variety of drapery, ray and crown-like structures, brightness and change of colour, and movement into low latitudes, they were the equal of any that had been seen for more than a century. And this was not surprising. The sun was going through the most restless period that had ever been recorded. Solar flares with their great blasts into space of ultraviolet light, x-rays and electrified particles had reached a higher level of intensity than ever observed before. The sunspots, our usual measure of solar restlessness, were breaking all previous records in their number and size.

For the past four to five years, solar activity, as measured by sunspots, has been getting less. A minimum should be reached in 1964 and 1965. As the number of disturbed areas on the sun

continue to get fewer and smaller so will the auroral displays. Strange to say, auroral activity lags behind solar activity following a sunspot maximum. Auroras continue in number, size and brightness at nearly the same level for a year or so past the time of peak activity on the sun. Then they rapidly get back into step with solar activity, and stay in step until the next peak is reached. This so-called getting back into step seems to have taken place during the past two years; and this is the cause for the rapid drop in displays. The reason for this persistence in auroras for a time past the solar maximum is still to be discovered. Perhaps the explanation will be obvious after we discover why the disturbances on the sun rise to peaks roughly every eleven years apart.

The International Geophysical Year with its world-wide distribution and use of complex devices added much to what is known about auroras:

with its cameras that took pictures of all the sky at one-minute intervals throughout the night, and gave the first reliable records on the distributions of auroras and how auroras changed with time;

with its radars that helped to fill in the gaps in the photographic records when the skies were covered with cloud as well as during the daylight hours;

with its specialized spectrographs that recorded the wave-lengths and brightnesses of the light coming from the aurora and from the sky to the north and south of it;

with its rockets fired into aurora from places like Churchill;

with its cameras and radio telescopes directed at the active regions on the sun;

and with its artificial satellites that detected effects due to the wave and particle radiations from these active regions as they entered our outer atmosphere.

With the enormous amount of data that was collected through these devices, one might expect that everything worth knowing about auroras has been discovered. This is not the case. Auroras are just one of the end effects of the exceedingly complex processes that bring electrified particles from the sun into our atmosphere. An aurora does more than indicate solar disturbances. When we see a widespread auroral display we can also be certain that radio

communications have been and are probably continuing to be disturbed; and that the earth's magnetic field is experiencing rapid changes in strength and direction. Both the radio and magnetic disturbance effects are large at high latitudes. Even weather processes may be influenced; though weather, as we experience it, takes place in the lowest ten miles or so of the atmosphere and not at the sixty miles and up for auroras.

Discoveries made during the International Geophysical Year, or I.G.Y., about auroras and sun-earth relationships responsible for them raised more questions than they answered. Many of the satellite and rocket experiments now in progress are planned to find the answers to these later questions—answers which are needed for our ventures out into space.

Another International Year, the International Year of the Quiet Sun started in January, 1964. Much the same observations will be made on auroras as during I.G.Y. just to see how they differ between active and inactive periods on the sun, or more technically between sunspot maxima and sunspot minima.

The auroral scientist will tell you that the light from auroras is caused by collisions of air molecules with electrons and protons. The latter are nuclei or massive portions of hydrogen atoms. Because of the relationship with sunspot activity, it is certain that the exciting particles came from the sun. If you ask him why auroras occur mostly in high latitudes, his explanation may appear complex—certainly involved. He will tell you that the earth is a huge magnet, and like a magnet has a magnetic field. He will go on by saying that it is convenient to picture this field as consisting of lines from the north to the south poles of the magnet. For the earth magnet the lines in space are parallel to the equator, but get closer and closer together as they bend downward to enter the earth in the northern and southern polar regions. He continues by saying that the electrons and protons carry electrical charges and that forces act on these charged particles as they attempt to pass through the earth's magnetic field. The greatest forces occur when the particles travel at right-angles to the magnetic lines, the least when they travel along or parallel to them. Over the equatorial latitudes the magnetic lines are at right-angles to the approaching particles, and are deflected back out into space long before they can get low enough to produce the auroral light. At high latitudes

the particles are travelling more nearly parallel to the magnetic lines, the repulsive forces are smaller and the particles get down to levels where the collisions with air molecules are numerous. As a result, the amount of light produced is sufficient to produce what we see as an aurora.

If you are even more curious about the whole business, and ask him how hard must be the collisions between air molecules and electrons and protons, his explanation will become even more complex. He will tell you that the discovery of the Van Allen radiation belts was the most spectacular achievement of I.G.Y., and that the outer Van Allen belt is something like a girdle. The inner and outer surfaces of this girdle parallel the lines of the earth's magnetic field. The inner side over the equator is about two earth radii distant, the outer surface three earth radii. The ends of the girdle are over latitudes in the North and South where auroras are seen most frequently. He will then tell you that charged particles getting into this girdle or zone at an angle to the magnetic lines spiral or circle around the magnetic lines, the spirals getting flatter or more nearly at right-angles to the lines as the particles approach the northern and southern edges of the girdle. As soon as the spiral gets flat or at right-angles to the lines the particles reverse direction, and travel back in the opposite direction to the other end of the girdle. There, they are once again reflected, and so travel backward and forward from one end of the girdle to the other.

If you ask him what all this has to do with the aurora, he will get purposely vague. He will tell you that he doesn't really know how the particles with their electrical charges get into the Van Allen zone, or how they get projected out of the ends and into the lower atmosphere to excite auroras. He will tell you that rockets and satellites detect the particles, and that I.G.Y. observations showed that auroras generally occur at the same times in the atmosphere below the ends of the Van Allen zone; when there is a big auroral display in the North, there is another going on in the South. He will at least leave you with the impression that there is much more that auroral scientists must discover about what is going on in the space between the sun and the earth and in the outer limits of our atmosphere before a complete explanation of auroras will be possible. Perhaps observations made during the

Year of the Quiet Sun, and observations now being made by our Canadian Satellite, *Alouette,* will help. *Alouette* is carrying devices which detect particles that excite the auroral light.

One of the most interesting discoveries of recent years has been that our eyes do not see the complete auroral display. Photographs with colour film often show reddish arcs and glows which were not visible to the people taking the pictures. Observations with spectrographs show that these result mostly from the collision between hydrogen nuclei, or protons, and air molecules. If you have a colour photograph of aurora showing red arcs and other features which you didn't see, don't be too alarmed about exposure times and such things. You probably have a picture of what was actually taking place.

A survey of this sort would not be complete without some mention of sounds from aurora. Many people claim to have heard swishing or rustling sounds. Scientists generally seem to be deaf with respect to these sounds. At least they have never heard them, possibly because there are strong arguments against sound waves getting all the way from auroras to the ground. Attempts to use ordinary microphones to record auroral sounds on magnetic tape have not been successful; mostly because the wind in blowing around the microphones makes sound waves of its own in which the auroral sounds (if any) are lost. Yet some recent observations suggest that auroral sounds do occur. A battery of spaced microphones, located outside Washington, D.C., detected low-frequency waves of too low a pitch to be heard by the human ear. These came from low in the north at times when the earth's magnetic field was disturbed. It is also at these times that we have auroras.

Very recently, two microphones, similar to the ones used at Washington were set up in northern Alaska. These were placed about a mile apart along a west-east line. Pressure waves in the atmosphere were picked up by these microphones, whenever there were auroras. These, like the Washington waves, were too low in pitch to have been heard by our ears. In the early evening the waves came mostly from the east, in the morning hours from the west. Just what have these to do with the high-pitched sounds which many people seem to hear from aurora? It is still something more to be discovered about aurora.

Scientists from their studies of aurora are discovering much about what is happening on the sun, in the space between sun and earth, and in the outermost portions of our atmosphere. Perhaps in another ten years or so they will be telling us that sounds can be heard and that aurora can be used to forecast weather changes.

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DR. W. E. VAN STEENBURGH

DR. Y. O. FORTIER

DR. R. THORSTEINSSON

23: Scientific Research in the Arctic

Bit by bit the magic and the mystery of the Arctic yield to man's energy, science and understanding. "No one can stand in these solitudes unmoved, and not feel that there is more in man than the mere breath of his body."

Ever since Pytheas of Massilia, the first polar explorer, reached the edge of what he called "the curdled sea" about 330 B.C., the Arctic has presented a challenge to man's endurance and ingenuity. The story of the exploration and discovery of the Canadian Arctic is, in fact, one of the epics of history.

Man's first deliberate look at the Arctic came through the eyes of explorers like Frobisher, Davis, Hudson, and Baffin in the late sixteenth and early seventeenth century, and later through those of Ross, Rae, Franklin and others in the nineteenth. Their expeditions, aimed mainly at finding a northwest passage, provided the first rough maps and varying amounts of scientific information. Later still, the demand for new whaling grounds and the urge to reach the North Pole sent men like Hall, Greely, Sverdrup and Peary north, after the fate of Franklin had been determined.

This period—roughly from 1855 to 1914—also brought notable advances in arctic science. In 1859, a clergyman named Haughton compiled the first geological map from samples sent back by the Franklin search parties. In 1881, a meteorological station was established in northern Ellesmere Island, during the first

International Polar Year. A few years later, Robert Bell of the Geological Survey of Canada studied rock formations on the north-eastern shores of Hudson Bay. He was followed by A. P. Low, who collected specimens of fish and plankton in Hudson Strait and rock samples from Ellesmere Island and Beechey Island.

At the turn of the century the Tyrrell Brothers explored much of the District of Keewatin. J. G. MacMillan studied rocks in Melville Island about the same time. Under Stefansson, the last of the heroic age of explorers, scientists gathered data on Banks Island and the other islands of the Arctic Archipelago, on the northwest coast of the Northwest Territories, and on the ice of the Beaufort Sea.

To-day, although there are no new lands to be discovered in the Arctic, research there is tinged with a sense of urgency. The future Canadian and world economy demands that the resources of the Arctic be surveyed and developed. National defence calls for a knowledge of polar conditions and an understanding of arctic phenomena. The need for accurate weather forecasting has led to the establishment of weather stations in the Arctic Archipelago. Canada's sovereignty over the Arctic makes it critically important that she assess its scientific and economic potential.

The Canadian North today is like a great outdoor laboratory, training ground and treasure chest combined. Since the second world war, survey and research have advanced with considerable vigour to determine the value and richness of the Arctic.

The way in which modern exploration of the Arctic has been undertaken can be illustrated by reference to the work of the Geological Survey of Canada. Many early arctic explorers chipped rocks or brought back mineral samples. Frobisher, in fact, led the first northern gold rush when he mistook iron pyrites for the precious mineral near the bay now named after him. But our knowledge of the geology of the Canadian Arctic was scanty until fifteen years ago. Canada's Arctic Archipelago has a land area of 525,000 square miles, and until then our only geological knowledge of this vast area was of isolated spots. On maps, these spots were splashed with those vivid colours the geologist uses to indicate different rock types. The Canadian Arctic resembled a huge carpet. All we knew about the carpet was the size, shape, texture and location of a few scattered tufts. Today the pattern

of the carpet begins to reveal itself. To investigate the geology of the Arctic, every ancient and modern technique of polar travel—from dog sledges to helicopters, from skis to light planes—has been pressed into service.

Systematic geological mapping of the archipelago began in 1949 when Y. O. Fortier took a party to Baffin Island. Others followed, using the traditional dog teams and small boats. Then, in 1952, the helicopter was introduced to northern work, enabling geologists to carry out preliminary surveys of vast segments of the North in remarkably short time. In 1955, the Geological Survey mounted "Operation Franklin" in which eight helicopter-supported parties covered a total of 20,000 square miles of the archipelago in a single season. Recently geologists have been using a light plane fitted with balloon tires that can land with ease on the flat, stony ground commonly found throughout the Arctic Islands. Thanks to the ingenious use of aircraft, the Survey has completed its reconnaissance of well over two-thirds of the Arctic, and will probably wind up this phase of the work by 1970.

From the work of these parties we have determined the broad framework of the geological structure—the skeleton, as it were—of the northern part of our continent. And the field parties have also added a lot of geological detail, or flesh, to these bare bones.

North America can be divided into two major areas—the Central Stable Region and an Unstable Region around its edges. At the heart of the Central Stable lies the Canadian Shield, made up of rocks that were old when the world was young. These rocks were laid down as deposits in long vanished seas, some 900 to 2,700 million years ago, during the geological era called the Precambrian. These old rocks, which lie exposed in a vast arc around Hudson Bay, have been twisted, shattered, dislocated and changed in their long history, and contain much of Canada's mineral wealth. To the north of the mainland they are exposed at the southern end of Banks Island, over large areas of Victoria Island, much of Boothia Peninsula, the eastern part of Prince of Wales Island, western Somerset Island, and the southeastern part of Ellesmere Island.

A glance at the map will show that the Canadian Arctic Archipelago is really the drowned edge of our continent. In ages past, the great Canadian Shield began to be worn down. Wind and

rain, frost and tide battered its surfaces and edges, and wore it away, little by little. Some of the material washed off settled in the shallow seas north of the shield. Here, in the geological region now termed the Arctic Lowlands, rocks such as sandstone, dolomite, shale and limestone were laid down in shallow seas. The Arctic Lowlands cover much of Banks Island, King William and Somerset Islands, and extend over the northern and western parts of Baffin Island and western Devon Island; they also form a narrow belt in southeastern Ellesmere Island.

North and northwest of the Arctic Lowlands lies another belt of rocks. This belt stretches for 1,400 miles, swinging across Melville, Bathurst and Cornwallis Islands, thence northeasterly through the Grinnell Peninsula of North Devon Island and the central and northern parts of Ellesmere Island. The rocks of this belt, like those of the Arctic Lowlands, are mainly limestone, dolomite, sandstone and shale. They reached a thickness of 40,000 feet and more at one time, and then were subjected to intense heat and pressure as they were pushed down towards the Canadian Shield by enormous forces. These forces came from the direction of the present Arctic Ocean, and resulted in the rocks being thrust up and folded into mountain chains.

In places, these mountains, now worn down to shadows and stumps of their former selves, still stand. Over a large area, however, they have disappeared under another set of rocks laid down since the mountain building period. This area, known as the Sverdrup Basin, is like a vast bowl that has been filling up with small pieces of rock for millions and millions of years; the filling up began 330 million years ago and ended about 60 million years ago. Over the years these deposits reached a thickness of 40,000 feet in places.

After these rocks were laid down they underwent all the processes that rock can undergo during millions of years of geological time. This changing of the rocks, which the geologists call metamorphism, involves twisting and faulting, folding and deformation. Mountains arose and were worn down, and the very rocks themselves altered under heat and pressure. Under the influence of these forces, limestone becomes marble.

The Sverdrup Basin, which seems to have promising prospects for oil and gas occurrence, covers the northeastern regions of

Prince Patrick Island, the northern parts of Bathurst and Melville Island, all of Mackenzie King, Amund Ringnes, Lougheed and Cornwallis Islands, the southeastern regions of Brock and Borden Islands, and the greater part of Ellef Ringnes and Axel Heiberg Islands, as well as the western and northern regions of Ellesmere Island.

At the far north west of Canada's Arctic Archipelago, beyond the Sverdrup Basin, lie the youngest of the rocks—those that make up the Arctic Coastal Plain. Here, in the northwestern parts of Banks, Prince Patrick, Brock, Borden, and Ellef Ringnes Islands, and on Little Meighen Island, are relatively thin rocks, a mere 700 feet thick. These young rocks appear to be the thin edge of the sediments that were mainly deposited in the Arctic Ocean, and on the Canadian Continental Shelf. This shelf runs out into the Arctic Ocean from Canada's northernmost island fringe for up to fifty miles, and then drops off sharply into the depths of the Arctic basin.

Since 1959, oceanographers and geologists, physicists and ice specialists, geographers and hydrologists, seismologists and meteorologists have been probing the secrets of the shelf and of the sea around and above it in one of Canada's largest co-ordinated assaults on the Arctic. This co-ordinated programme, known as the Polar Continental Shelf Project, has resulted in the development of many new instruments and techniques. The Project has introduced portable navigational equipment that gives instantaneous positions and a hydrographic sounding device, light enough to be carried by helicopter, that eliminates the need for drilling holes in pack ice. Another important step was the development of a remote-reading gravity meter for observations on heaving sea ice.

These keys to the scientific understanding of natural phenomena have helped, and still are helping, to unlock the mysteries of the Canadian Arctic. We have come a long way from the simple geologist's hammer and the rock casually picked up on an overland sledge journey. The vigorous programme of arctic research being carried out by the Geological Survey of Canada and by the Continental Polar Shelf Project is not only furthering national interests, it is also making major contributions to world science.

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DR. Y. O. FORTIER, *Chief, Economic Geology Division, Geological Survey of Canada, Ottawa. Born Quebec City, 1914. Attended universities of Laval, Queen's, McGill, Stanford. Holds B.A., B.Sc., M.Sc., Ph.D. Wide experience leading field parties in Canadian Arctic Islands since 1947. Awarded Massey Medal of the Royal Canadian Geographical Society, 1964. Authority on structure of Canadian North and its oil potential. Fellow, Royal Society of Canada.*

DR. R. THORSTEINSSON, *Chief, Arctic Islands Section, Geological Survey of Canada, Ottawa. Born Wynyard, Sask., 1921. University of Saskatchewan, B.A. 1944. University of Toronto, M.A. 1949. University of Kansas, Ph.D. 1955. Wide experience in Canadian Arctic Archipelago. Fellow, Royal Society of Canada.*

TREVOR HARWOOD

24: The International Geophysical Year

It seems the world's scientists—to use the word loosely—get along with each other better than the world's politicians. They are held in such fascination by the wonders of land, sea and air that they have less interest for man's vanities.

The International Geophysical Year signified a period of time which lasted from 1 July, 1957, to 31 December, 1958. It was thus actually a year and a half, the reason for this being that the so-called year had to cover both the Arctic and the Antarctic for a full climatic year and since the seasons between the two hemispheres are six months out of phase, an extra half-year period had to be added.

The enterprise was initially inspired by a general desire of earth scientists for more knowledge and understanding of our planet and the sun. It was supported almost universally by governments throughout the world because it was obvious that there might be, and to date there have been, benefits of great importance to mankind.

Actually, the I.G.Y. developed out of rather less sophisticated proposals for a Third International Polar Year.

The First International Polar Year came about when the novel idea of synoptic weather, aurora and magnetic observations, that is a series of comprehensive and preferably simultaneous observations, was being advanced with some vigour. Carl Weyprecht, a lieutenant in the Austrian Navy, realizing the great value of such synoptic programmes, proposed such a study of the polar regions.

Weyprecht unfortunately died before the beginning of the Polar Year but the fuse had been set.

When the final Polar (planning) Conference met in St. Petersburg in August 1881 delegates from ten nations attended, and eight nations co-operated in the establishment of fourteen polar stations through expeditions in the year 1882-1883, three of which were in Canada. The Canadian stations were:

Fort Rae (Great Slave Lake) operated by Britain

Kingua Fiord (Cumberland Gulf) operated by Germany

Lady Franklin Bay (Ellesmere Island) operated by U.S.A.

Since the advocates of synoptic studies had at that time been the magneticians and meteorologists, the bulk of the scientific studies carried out were devoted to these two fields.

Transportation and communications in those days being extremely primitive, most of the expeditions set out in 1881, returning in late 1883, and one in 1884. The last, the United States expedition to Lady Franklin Bay, was in the field until June 1884 during which time the expedition suffered the loss by starvation of twenty out of the twenty-six men on the retreat from Fort Conger to the south. The actual site of the final disaster is not far from the Royal Canadian Mounted Police post at Alexandra Fiord.

It was not until 1891 that the fifth and last international conference met in Munich to consider the working up of the Polar Year data, although by this time most, though not all, of the reports were in.

Some forty-five years after the First International Polar Year the feeling began to grow that in view of the great advances in techniques for observing physical phenomena, the time was ripe for a Second International Polar Year in 1932-33. At the first conference, or polar commission of interested scientists, resolutions were passed expressing the opinion that auroral, magnetic and meteorological observations should be carried out in the Arctic and Antarctic. The programme of observations was thus effectively expanded over the First Polar Year as was the geographic area which became bi-polar.

Unfortunately, during the 1930's severe economic depression set in all over the world which made it extremely difficult for participating countries to provide funds. The Polar Commission, however and just in time, received a grant from the Rockefeller Fund

which fortunately allowed the magnetic and aerological programmes to be carried out and even extended.

The stations in Canada for the Second International Polar Year were:

Chesterfield Inlet,
Coppermine,
Cape Hope's Advance,
all operated by Canada
Fort Rae, operated, as in the First Polar Year, by Britain.

Due to the paucity of stations with limited observations the Second Polar Year was rather a feeble effort compared to the First, although of course the data produced were more sophisticated, particularly in the case of the auroral studies, terrestrial magnetism and the introduction of ionospheric physics, a new research tool.

In 1950 the American scientist Dr. Lloyd Berkner proposed that as advances in techniques had again been so great over the war years a Third International Polar Year was needed only twenty-five years after the Second. This fortuitously was also the peak of the sunspot cycle. Subsequently this proposal was enlarged and enhanced when the International Association of Meteorology and the International Association of Terrestrial Magnetism pointed out the desirability of observations being extended to low latitudes, particularly as in certain respects much less was known about the equatorial regions than about the polar regions.

The Executive Committee of the World Meteorological Organization, a United Nations body, suggested an International Geophysical Year would be more useful than a Polar Year. So it was that the International Council of Scientific Unions, at a meeting in Amsterdam, decided to support an I.G.Y. or, as it was known in French, an A.G.I. This meeting took place in October 1952 or five years before the event. A special I.G.Y. committee was formed and this committee agreed that the programme of the I.G.Y. should be arranged with a view to selecting specific earth planetary problems and that special attention was to be paid to the arctic and antarctic polar caps together with observations along three specific meridians, these meridians being 70°-80°W, 10°E and 140°E. So as to undertake periods of concentrated observations it was also proposed that special "World Davs" were to be used and in the

case of sunspot phenomena "alerts" and special "world" intervals were to be employed.

Finally, when the I.G.Y. commenced, observations were carried out in what might be described as thirteen main fields or disciplines. These were meteorology, geomagnetism, auroral studies, ionospheric physics, solar activity, cosmic rays, latitude and longitude, glaciology, oceanography, seismology, gravity, and meteor studies.

In relation to the cold war the proposal for the I.G.Y. came about soon after Stalin's death following which there was a period of gradual reorganization in the higher levels of the Communist party. Nikita Sergeyevich Kruschchev subsequently became Chairman of the Communist Party, and being more liberal or perhaps less doctrinaire, there came to pass a gradual thaw, certainly in scientific communications between scientists in the West and East. The Soviet Union enthusiastically endorsed the principles of an I.G.Y. and co-operated even to the extent of inviting an I.G.Y. meeting to Moscow and offering to organize a World Data Centre.

These World Data Centres were to be repositories of all data collected, the U.S. to organize one and the U.S.S.R. another. To avoid too obvious a division between East and West a third series of Data Centres for individual disciplines was organized in various countries, mainly Western Europe, Japan, and Australia.

The I.G.Y. organizing committee also was truly international, finances being received from all countries, particularly the U.S., U.S.S.R., Great Britain, and the United Nations (UNESCO).

In Canada the programme was wholeheartedly supported by the government and universities on a proportional basis probably slightly larger than the United States and the U.S.S.R. It involved new or enhanced programmes at seventy-six different stations, of which twenty-six were in the Arctic, a considerable jump from the three in 1882 and the four in 1932.

Much of the understanding which we have today of the physical processes such as atmospheric circulation, the circulation of the Arctic Ocean, the regime of the glaciers, the many idiosyncrasies in the radio communications due to the peculiar structure of the earth's magnetic field over the Arctic and its effect on the ionosphere, has developed from the International Polar Year programmes and I.G.Y.

However the amount of data collected during the I.G.Y. was tremendous and it will be many, many years before the final analysis will be made. As an example of this, just as the I.G.Y. was beginning, a new paper on ionosphere physics in northern Canada was published based on the data collected during the Second International Polar Year some twenty-five years earlier. Thus one can assume that for the next twenty years or more results will be coming out which will in all probability be extremely important in future developments, particularly in communications, climatic studies, possibly climatic control, space research, oceanography and other research fields.

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DR. G. HATTERSLEY-SMITH

25: Operation Hazen

And now a particular I.G.Y. project is pictured in detail, on a mountainous arctic island where average December temperature was —47°F., where a rum-soaked fruit cake lightened the darkness, where transport was everything from Dakotas to tractors to dog teams.

The Defence Research Board chose the Lake Hazen area as a suitable field of operation for a Canadian party during the International Geophysical Year of 1957-58. There were two main reasons for this choice. First, the accounts of the early explorers indicated an unusual climate and environment which seemed worth investigating; secondly, the nearby ice cap and glaciers provided a suitable locale for glaciological studies which formed a main part of the I.G.Y. programme.

The imposing mountain ranges of northern Ellesmere Island form the northernmost frontier of Canada against the Arctic Ocean. In the central part of these ranges elevations reach 6,000 feet over a fairly wide area, and most of the land is ice-covered. The higher peaks are bare, and some of these reach a height of more than 8,000 feet. The mountains fall southward to Lake Hazen, which occupies a broad and deep valley just south of latitude 82°; the lake is forty five miles long and up to seven miles wide, and is remarkable in being the largest body of fresh water so far north in the world. Until 1957 this interior region of northern Ellesmere Island had been visited by only a very few exploring parties after its discovery by Greely, the leader of the United States expedition during the First International Polar Year of 1881-82.

Lake Hazen was certainly a happy choice, both for the research possibilities and for the solution of problems of supply and daily living in a remote area. The lake itself provides good landing conditions for aircraft, on the ice for wheeled or ski-wheeled aircraft in spring, and on the water for flying-boats in most summers, while icebreakers can sail up one of the fiords on the east coast of Ellesmere Island to within twenty miles of the lake in any summer. The climate is characterized by an unusually low prevalence of wind and cloud. In winter the white expanse of lake below ice-capped mountains rising to 8,000 feet, in summer the varied wildlife and rich flora near the lake and in the foothills where the rocks are colourful in browns and reds, make one of the most attractive settings in the Canadian Arctic. It was here that the Defence Research Board sought to provide a modest but adequate field base for scientists in various disciplines from government departments and from universities.

Each spring from 1957 to 1961 airlift for men and supplies to Lake Hazen was provided by the Royal Canadian Air Force in C-119 ("Flying Boxcar") and ski-wheeled DC-3 ("Dakota") aircraft; the R.C.A.F. also provided relief flights in the late summer of 1958, 1959 and 1961 in "Canso" or "Albatross" amphibious aircraft. In 1957, 1958 and 1959 Hazen Camp was resupplied in mid-August by the United States icebreakers *Eastwind, Atka* and *Westwind* respectively; the ships' helicopters transferred cargo from the anchorage in the fiord to the camp, and evacuated members of the party. During the course of five summers, research has been conducted by government and university scientists in the fields of glaciology, meteorology, geology and geomorphology, soil science, gravimetry, geomagnetism, biology and archaeology. A total of twenty-five men participated in the field work of five summers; ten of these men spent more than one summer in the area, and in addition four of them maintained a meteorological station at Hazen Camp throughout the 1957-58 winter.

The beginning of the I.G.Y. programme coincided with the end of the "Shoran" mapping programme of the R.C.A.F. and Geodetic Survey for which Lake Hazen was the most northerly station. On 28 April, 1957 our "Flying Boxcar" made wheeled landings in ten to twelve inches of loose snow on the smooth lake ice near the "Shoran" party's camp which had been established by

ski-wheel "Dakota" near the north shore of the lake a few days previously. Housing, fuel, food and equipment to last two years were strewn over several hundred square yards of the lake ice. It was necessary for the main camp to be on the north shore of the lake to provide easy access at all seasons to the glaciers and ice cap to the north; fortunately the nearest point on the north shore provided an excellent site on sand fifteen feet above the level of the lake. The later landings on the lake were made on an airstrip prepared by a tractor carried in on the first flight. By the end of May the two wooden-frame and insulated canvas huts had been erected where they still stand in good condition after eight years. Our glaciological camp at an elevation of 3,400 feet on the Gilman Glacier twenty miles to the north, was established by ski-wheel "Dakota" in 1957, and was similarly reopened in subsequent years. In 1958 a "Dakota" was also used to fly two field parties to one of the fiords on the north coast whence they traversed back, carrying out geological, gravity and survey work on the way; flights were also made to Ward Hunt Island on the north coast and Fort Conger, Greely's old winter quarters fifty miles to the east, where gravity measurements were made. The DC-3 was also used for laying caches to east and west.

Up to early July a light snowmobile which could haul a two ton sledge was used on and near the lake. Towards the end of June, when the melt season was in full swing, the tractor became of limited use as it could not cross streams. Dog teams were successfully used away from the lake in the spring for access to the fiord region to the south-east of the Ruggles River draining Lake Hazen, where the river ice was unsuitable for tractor travel. Later, after the snow had melted, the dogs were used for packing, and were employed in this way for a geological traverse to Alert weather station ninety miles to the north-east. Each dog could carry up to twenty pounds leaving the men with a fairly light load. On the ice cap and glaciers motor toboggans and dog teams were used throughout the summer to haul loads up to 1,500 lb. on "Nansen"-type ski sledges. Ice conditions on the lake varied widely from one year to another. In one year the lake was completely ice-free by the first week in August, in other years travel by boat was restricted or completely prohibited by ice conditions.

Standard grocery items made up the bulk of our party's food. Dehydrated items were chosen wherever possible, and it was considered a false economy to take in food of other than the best quality. The wishes of all members of the party were considered in the ordering of the food. The basic foods were supplemented for field parties by various special items developed by the Canadian Army and the Defence Research Medical Laboratories. At the base camp good use was made of arctic char caught in the lake. For the glacier party rations were specially packed in aluminum boxes, each weighing about sixty four pounds when full, and containing a generous ration for two men for two weeks. Special items comprised meat bars, oatmeal blocks, shortbread bars, fruit cakes and freeze-dried meat. Meat bars were extensively eaten throughout the operation, and made up about half the intake at the glacier camp. They were either eaten from the packet on the trail, or were made into stews with dried vegetables, and spaghetti or rice. Oatmeal blocks and shortbread bars were staple items of trail lunches. A special rum-soaked fruit cake proved very filling and very palatable, and useful for giving quick energy on the trail or after a hard day. The freeze-dried meats included steaks, pork chops, turkey and hamburger. These items, soaked in water for five minutes and cooked in the appropriate way, were much appreciated. At an isolated station there is considerable morale value in serving steaks and other forms of dehydrated meat that are virtually indistinguishable from fresh products.

The main scientific effort was directed into glaciology, and the related field of meteorology. We now have a good idea of the thickness and regime of the ice cap and glaciers, and of the glacial-meteorological conditions: ice thickness ranges up to 2,600 feet, and in general there is a small loss of ice mass year by year on the main glaciers, but little change in the position of their snouts. The smaller ice caps and glaciers are thinning and retreating appreciably. The meteorological record at the main camp in 1957-58 was the first extending over a full year from an inland station in the Canadian Arctic Islands—all the permanent weather stations are situated near the coast. The mean temperature during the winter months of 1957-58 was much lower than at any other station, but there was a higher proportion of calm weather. December was the coldest month with a mean temperature of

—47°F, but the lowest temperature of —68.5°F was recorded in early January. The precipitation did not exceed two and a half inches of water, mainly in the form of snow, for the year ending in August 1958.

In the field of geology it is of interest to note the coal-bearing strata which border the north shore of the lake and which provide a very fair fuel, and the fact that the whole area was at one time under a thick ice cover. The great depth of Lake Hazen, nearly 900 feet in parts, seems to be due to a combination of faulting and glacial erosion. For this high latitude the fauna and flora are of unusual richness. It is estimated that there are about 200 muskoxen in the vicinity of Lake Hazen; fox, wolf and hare are common, but few caribou have been seen. Evidence of depredation by Peary's Eskimo hunters is shown by groups of muskox skulls at several places near the lake. Lemmings were very abundant in 1957, although few were seen in subsequent years. A total of eighteen species of birds have been observed in the area and numerous arctic char, up to three feet in length and twelve pounds in weight, have been caught in the lake. More than 150 species of insects and more than 100 species of flowering plants have been collected from the area.

The archaeological sites in this remote area have a particular fascination. The excavations on behalf of the National Museum show that the sites range back 1,000 years, but that the Lake Hazen Valley does not appear to have been a major migration route, as some authorities have postulated. A few Eskimo hunting parties have visited the area since 1900, but apart from this, the dating of a rich site at the head of the Ruggles River and other evidence indicates that the Lake Hazen Valley, even as a seasonal hunting area, was abandoned 500 years ago. Relics of Greely's parties were found along the south shore of the lake, and one of their records in a cairn near the north shore; the winter house of Peary's Eskimo hunters in 1906 was also found in ruins at the east end of the lake.

Detailed and reconnaissance studies in various disciplines from Hazen Camp between 1957 and 1962 have led to the publication of a considerable number of reports and papers. The experience gained and the work accomplished point the way to the very many problems awaiting investigation. The Lake Hazen area is only

one part, though in some respects the most interesting, of northern Ellesmere Island—a region about as large as New Brunswick which offers virgin fields of scientific study for many years to come.

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26: The Inside of the Earth

Meanwhile below all this ice and snow scientists are probing the earth itself, into its very hot solid mantle and, in their minds, into the liquid white-hot molten iron of its core. "There are more things in Heaven and Earth, Horatio, than are dreamt of in your philosophy."

I want to talk about the inside of the earth.

These days we hear a great deal about outer space which is being explored by astronauts, and on clear nights we can sometimes see artificial satellites crossing the sky. But inner space also exists beneath our feet, and this is less well known. Even in the deepest mines no man has been down more than two miles into the interior of the earth, and no drill has yet penetrated more than five miles. Thus inner space—the inside of the earth—is less explored than outer space, but even if we cannot visit the inside of the earth, we can still find out quite a lot about it.

In order to find out whether a baby has swallowed a safety pin, it is not necessary to operate; one can use x-rays. In the same way that x-rays tell us about the insides of people, so earthquake waves can tell us about the inside of the earth. When a large earthquake occurs, the whole earth is slightly shaken and the waves travel through the earth, taking about twenty-three minutes to go from one side to the extreme opposite side. These waves bounce around inside the earth and seismologists by recording them can find out something of the inside of the earth in the same way that people study x-ray photographs to find out about the insides of people and other objects.

It has been discovered that the earth has three main parts. It is arranged like a soft-boiled egg which has a shell, a white and a yoke. We call the shell of the earth the crust. That is the part we live on and can see. Of course it is made of stone and rock. At a depth of a few miles this appears to give way to another denser, heavier type of rock which constitutes the bulk of the earth. This part which corresponds to the white of a boiled egg is called the mantle. It is solid like the crust, but most of it is white-hot. In the extreme central part of the earth there is a part like the liquid yoke in a soft-boiled egg or the core in a golf ball: that is what we call the core of the earth. This is believed to be made of white-hot molten iron.

Now, we are quite certain that the core is molten, and that both the crust and mantle are solid. We cannot see the mantle, and we are not sure what is the difference between the crust and the mantle. In order to explore the mantle, the white of the egg, if you like, a plan has been made to drill a hole into it. The Americans, and perhaps the Russians, plan to drill holes in the floor of the ocean to see if they can reach the mantle and get specimens of it. They have to drill at sea because the crust is thinnest there. The Americans call their scheme the "Mohole".

One thing that we do know about the inside of the earth is that it is very hot. Miners find that the temperature is considerably warmer at depths of one or two miles than at the surface. Indeed in many mines this heat places a limit on the depths to which mining can be carried out. Some working mines would be over a hundred degrees fahrenheit if they were not refrigerated. Since temperatures of over a hundred degrees may be reached at depths of one or two miles, you can imagine the temperature in the earth at a depth of a few tens or hundreds of miles is very hot indeed. Thus it is perfectly certain that the greater part of the earth is white hot. And this is probably the reason why the core of the earth, the part corresponding to the yoke of an egg, is liquid, white-hot iron, but pressure keeps the mantle solid.

Consider now the behaviour of the inside of the earth. The inside of the earth is certainly rigid to short disturbances such as earthquakes. The motions of earthquakes travel through the mantle and the crust of the earth in such ways as to indicate that they are rigid solids—as rigid as steel or rock. The reaction of the earth to

tides is similar. Tides have the same effect on the earth as though the whole outer part of it was rigid and only the liquid core was fluid. But what happens over extremely long periods of time may be a different matter. One must remember that the earth has had an enormously long history. Its history extends back not only for millions of years, but for hundreds of millions of years—even for a few thousands of millions of years. And it is impossible for us to tell exactly what happens to solid materials when they are exposed to slow pressures and forces exerted for hundreds of millions of years. It seems probable that even the most solid rock if it is white-hot and exposed to very great pressures and forces for a long period would creep, or flow and move very slowly.

This appears to be part of the cause why mountains are built. Mountains have been pushed up. It is much easier to realize how this could have happened if you realize that below the depth of a hundred miles or so the whole inside of the earth is white-hot. In detail there are a number of theories about how mountains have been built. We see mountains on the surface of the earth, but if we think about it, we can realize that what we see is just a superficial expression; that the mountains are really built by forces that operate inside the earth. Now a long time ago, about three hundred years ago in the time of Newton, when people first started to think about this, they suggested that the earth had at one time been very hot; hotter than it is now, and that it must necessarily have cooled and that in cooling it would have contracted, and the contraction could have wrinkled up mountains in much the same way as a drying apple shrivels and pushes up ridges on its surface.

However, the discovery of radioactivity made it doubtful if the earth has been cooling. It is possible that the uranium and potassium and other slightly radioactive elements inside the earth are generating more heat than is lost and hence that the earth is warming up and not contracting at all.

Another line of thought was introduced by the great German geophysicist Wegener and by the American geologists Baker and Taylor, about fifty years ago. They noticed that some of the margins of continents fitted together very well. For example, they noticed that the Atlantic coast of Africa and the shores across the Atlantic of South America could be fitted together quite well. You can try looking at this on a globe, and you'll see there is an

excellent fit. There is also a reasonably good fit between the shores of Europe and North America. These men therefore suggested that the continents had moved apart. To many this idea that continents could actually be moving about seemed so strange that it was hotly denied. On the other hand, it is very hard for us to visualize what would go on in the vast and hot interior of the earth if slow forces were operating for hundreds of millions of years. This idea has gradually penetrated, and the idea that the continents could have moved apart is now being accepted by an increasing number of scientists. Two things which have been discovered recently make this seem more likely.

One is that the exploration of the floor of the oceans, which was started in a large way during the International Geophysical Year, has shown that there are great rifts or fractures on the floors of the oceans. Magnetic measurements made along some of these have suggested that large horizontal motions have occurred. Other fractures seem to be rifts along which the ocean floors have spread apart. Some of these fractures seem to have moved by more than a thousand miles. If displacements of a few thousand miles have occurred on the floors of the oceans, it seems possible to believe that continents have been carried along and that they might have drifted apart.

A second new observation is that magnetic measurements made on rocks have shown that the position of land masses relative to the north and south magnetic poles have varied. This fits older observations made of past climates. You are well aware that in the Arctic and Antarctic there are coal and signs of oil. Drilling is now going on in the Arctic for oil. It seems very doubtful whether oil and coal could have been formed in the polar regions if they had been as cold in the past as they are today. So it seems likely that a change has occurred in climates. Some people have argued that these observations can be explained by world-wide changes in the earth's magnetic field and in climate. Another possibility which is being increasingly accepted is that the continents have moved apart and that they were moving in different directions in past times.

We are now in a very exciting time in the study of the earth, for we can expect soon to solve this riddle. If the continents have indeed been moving it will seem extraordinary and we will

still have the job of plotting their motions throughout geological time.

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More About These Matters

Each of the subjects discussed in this book has a "literature" of its own – whether in book form, pamphlet, periodical or learned paper. Enquiries as to this background material, its source and availability, should be addressed to:

Information Services Division,
Department of Northern Affairs and National Resources,
Ottawa, Ontario

Conclusion

This book's distinction has been the authority, the personal experience and the knowledge of each contributor. The articles have given us many windows into the Arctic.

As a conclusion the editor sought a general perspective, a long gaze, in which the specialized views would find focus and added meaning.

The man best qualified to do this was R. Gordon Robertson. At the time of inviting him he was no longer Deputy Minister of the Department of Northern Affairs and National Resources, and Commissioner of the Northwest Territories, but had gone to even broader responsibilities as Secretary of the Cabinet and Clerk of the Privy Council. But the North will always be close to his heart, and he agreed to give our book its summary. "Is it all right if I borrow some bits from earlier speeches?" he asked. It most certainly was, and is.

On September 17, 1963, McGill University conferred upon Gordon Robertson the degree of Doctor of Laws, honoris causa. *These lines from the citation tell the story:*

There was a time when Canada's north was poorly governed. Our neglect was such that some could even question our sovereignty. Now this is all changed. Especially in the past ten years we have fully awakened to our responsibilities. We no longer need blush when we meet a Danish or a Russian colleague. Throughout this decade of advance, Gordon Robertson has been the man at the helm.

R. GORDON ROBERTSON

The Long Gaze

The Canadian North is one of the last large under-developed regions of the world. There are few other areas of great size that have not been occupied, in so far as they are capable of it, although many remain still to be developed.

The tantalizing possibilities – the great uncertainties and obscurities – of the tremendous area at the top of our continent lend a special mystery to the role the future has in store for Canada as a whole. An important element of the answer to the national riddle depends upon the prospects of the North.

Many question marks hang over the possibilities of the North. But while there are a lot of unknowns, there are also a lot of things we know – and all of them suggest that the economic future is likely to be interesting, though full of problems and difficulties. It is safe to assume that the source of the largest part of its economic development is underground. There are, it is true, some millions of acres of arable land in the Yukon and the Mackenzie Valley and, while it may come as a surprise to many, on much of that land crops of grain and vegetables can and undoubtedly will be successfully grown. There are also extensive areas of commercially valuable forest far, far north of any regions that we have thought about in the past as being important sources of timber and timber products. These are even now beginning to be used, and most of them will probably one day have value. There are also commercial fisheries, some in existence, others that can be developed, which will be worth several millions of dollars each year. However, when all these surface resources have been developed to their fullest degree – as developed they almost certainly will be – they will still be far over-shadowed by the growth that will be based on the resources that lie below the surface. The main economic possibilities of the Yukon and of the Northwest Territories lie in the domain of minerals.

We know that many of the sources of minerals of all kinds that

have been most accessible in the past have been or are being exhausted or seriously depleted. As this has been going on we have been made aware in the most conclusive of all ways – by the growing interest and activity of men with money to invest – that the North has been blessed with large mineral deposits. Just how extensive we do not know, because we have as yet investigated so little of that immense region.

In the Yukon the prospects appear to be good for a wide range of metals as well as asbestos, oil and gas. Underlying the Mackenzie Valley there is a very large area of sedimentary rocks which is an extension of the oil and gas regions of Alberta. In the Canadian Shield, which covers more than half of the Northwest Territories, geologists advise that we can expect to find virtually every mineral except those laid down under tropical conditions. The regions that have created the mineral wealth of Ontario and Quebec are tiny spots within the vastness of the Canadian Shield. Its length and breadth throughout the Northwest Territories give a hint of the kind of development that we can expect to see there. The Shield extends into the Arctic Islands but at the extreme north of these we come into a new geological region and again the evidence suggests that there are likely to be extensive resources. This most northerly region – called the Innuitian region – has scarcely been examined at all. The studies that have been undertaken indicate a near certainty of deposits of oil and gas.

There seems little doubt that there will be a steady and very substantial growth in the world consumption of minerals. We have mounting evidence that the North contains extensive and rich deposits – although we know too that other areas of the world are similarly endowed and do not suffer some of the disadvantages that a harsh climate imposes on arctic and subarctic development. Is there any reasonable likelihood, having in mind the problems posed by weather, vast spaces and transport, that enough of our northern resources will be available at low enough costs to be economic? To that question we must respond with all of our energy, all of our scientific skill, all of our imagination.

What about the Arctic's human future? What is likely to become of the people who live there and whose home it was long before we came on the scene?

The Indians and Eskimos of the North are losing a way of life – a way of life that they understand and to which they are adapted. And why are they losing it? Because of us – the white men who have pushed in, and who are pushing in more and more. Neither we nor they can turn back. The damage – if damage it is – is done. The old way of life of these people has been seriously disrupted and will gradually disappear.

It is not that we have actively sought to destroy their way of life. Not at all. The missionaries who taught that it was wrong to kill new-born girls or to desert the aged or disabled – or to assist in their suicides – were not intending to undermine the old way of life. But they helped. The limited wildlife resources of the North on which these people precariously depended had dictated the earlier practices. The traders, providing rifles, did not intend that these should cause game to diminish further still – but they too have helped. Virtually everything the Whites have done has helped, in one way or another, to ensure that, in the long term, the old life on the land could not last.

But though there is an undeniably tragic element in this story of the Eskimo and Indian, we would be doing them, and ourselves, an injustice if we did not recognize too the exciting "progress" the native peoples have been able to make – and what that progress has meant to the North.

To talk of progress one must define it, and although I realize the presumption that goes with any one-breath definition of such a complex term, I suggest it really means the broadening of human possibilities. The achievement of progress in the public domain means to enlarge the spirit of man, to enable him to bring out his best qualities, to give him the opportunity to reach, power to grasp, purpose to hold and promise to build.

In this sense, the last ten years have been years of progress for the native people of the North. How is this to be measured? While conditions are far from satisfactory, they are living longer and their health is better. The tuberculosis monster that boasted a 475 per 100,000 incidence in 1952 has been virtually beaten. There are thirty-one hospitals today – up from nine ten years ago. The significance here is not so much the negligible increase in beds but the benefits derived from treatment centres close to the people. The death rate has been halved in ten years.

But are we talking of extended life or merely lengthened existence? The problem of shelter has been attacked: the solutions tried are many and though incomplete they have narrowed the gap. Nearly 500 subsidized houses have already been provided and co-operatives and other programs are moving to fill the remaining need, which, with all that has been done, is great indeed.

The land remains harsh and so colours the struggle for subsistence. But black starvation is no longer a threat, mainly because communication is much better. With defensive installations of the cold war came massive investment in transport and communication facilities. The CBC Northern Service expanded its activities and enlivened its interest. Radio and aircraft have cracked the arctic solitude and by generously dispensing gregariousness have humanized the barrens. Today when one calls for help the odds are very good that the answer will be more than the whistling winds.

Has this extended, better protected life also become a richer life? Yes, if riches are smiling children able to attend school and receive the education on which future possibilities depend. Education facilities now are enjoyed by eighty per cent of Eskimo children, and almost all the other children of the North. Yes, if riches are the opportunities afforded by the seventeen co-operatives that fish, seal, log, carve, print, sew, build houses and boats and sell snacks. Yes, if riches are artistic expression: sculptured stone, printed designs, fashioned furs that speak Eskimo even in places where no Eskimo has ever been and that also bring livelihood as well as pride to their creator.

But is all this progress or is it simply an attempt at replacing values lost or killed? Human growth is not a hot-house plant but thrives on reality, and appreciable progress has been made in the contact between the man of the North and his fellow citizens.

In former years the North was visited mainly by heroic folk – heroic either in virtue or in its absence. The last ten years saw an increase in the number of those going to the North who were more of the bread-and-butter type. They have their weaknesses but they do reflect a truer picture of the civilization that spawned them. That the northern way of life must inevitably marry its

heritage to the age of the atom is a certainty. The Eskimo can no more remain apart from it than can the peoples of Africa and parts of Asia where similar revolutionary processes are going on. The concern of authentic civilization is really that this marriage will preserve as much of the healthy positive values of the old heritage as possible. To do this requires more than planning and spending; it requires living and it is precisely because there is a great deal of sincere, hard working, apartheid-free living taking place in the North today that I believe our northern original inhabitants are indeed making progress.

The Eskimo people are faced with a very difficult period. The disruption of old patterns of life, old customs, old standards of value, can produce many casualties. But it is just possible that the northern people, may in the longer term, be better off than some of our native people in southern Canada.

I venture the prediction that the North will prove to be the first part of Canada in which we really drop our colour line. Communities are now growing up where people of white race, of mixed blood, and of Indian or Eskimo race (or both) live side by side in the same type of house, with their children playing together and going to the same school.

I visualize a future in the North in which the administration, the mining, the operation of airfields and trains and machines, the buying and the selling and all the countless tasks of life from the lowest to the highest are done by people who do not enquire whether the man above, below or alongside them is an Indian or an Eskimo or a White. They will have been educated in the same schools, and will have played on the same village streets. The North will not then be run by us outsiders, with the real owners looking on. It will be run by the people who live there. It can be done. Greenland has gone a long way toward that goal and I am convinced that we can do it too.

Just as the conquest of outer space is providing a new challenge to mankind generally, so the conquest of the Arctic presents a peculiarly Canadian challenge and, we hope, a much needed Canadian opportunity. I suspect it is this prospect – of a greater national personality realized through the new prospects of a uniquely Canadian "space challenge" – that has caught the imagination of this country in recent years. Critics can argue

that such an idea is vain: that the Arctic cannot and will not be economically important enough to provide so great a difference to Canada. If, as economists usually believe, economics were everything, such a reaction might be correct. Yet, if we are to learn anything from our search for ourselves, we should by now have discovered that a nation does not live by gross national products or seasonally adjusted employment indices alone. It won't live long in this modern world without them – and without their showing a pretty healthy condition in the national heart, lungs and digestive system – but they are not enough. A nation must have a picture of itself as somehow unique. There has to be an ethos and a spirit that hold the people together with a sense, not only of sharing something in common, but of having a something that no other nation quite has. There must be a mystique and a romance that enable the national household to survive the strains of life.

The Arctic is of importance to Canada above all other nations with the sole exception of the Soviet Union. That country has long recognized that the Arctic has great significance for it. It has directed a wealth of effort, intelligence and knowledge to the exploration and investigation of the special nature and problems of the far North. In Canada we have not. There have been distinguished individual exceptions – in general, however, our people, our governments and our universities have until recent years shown little interest in an area with which Canada has a unique association.

Let us not be shy of pushing ahead. Some may scoff at overly-exuberant predictions, as there were those who scoffed in similar vein at the apparently barren stretches of the west. A learned British periodical of the 1880's castigated the construction of the Canadian Pacific Railway as a fatuous waste of money and material. It said:

". . . British Columbia is a barren, cold, mountainous country, that is not worth keeping. It would never have been inhabited at all, unless by trappers of the Hudson's Bay Company, had the 'gold fever' not taken a party of mining adventurers there; and ever since that fever died down the place has been going from bad to worse. Fifty railways would not galvanize it into prosperity . . ."

"In Manitoba those who are not frozen to death are often maimed for life by frostbite. Ontario is poor and crushed with debt. It is certain to go over to the States, and when that day comes the Dominion will disappear."

Our history has been replete with predictions of doom and disaster. Our country has a long record too of having much of it dismissed as useless, uninhabitable and sterile. Labrador, with its vast deposits of iron, enormous quantities of electric power and other resources, was "the land that God gave Cain". Voltaire dismissed Canada totally as *quelques arpents de neige*. We today would be wrong to give too much weight to hasty and pessimistic conclusions about the North. They may be right – but it is just possible they are wrong. And if they *may* be wrong, we would surely be short-sighted if we did not devote a reasonable part of our wealth and effort to a full assessment of all the opportunities the North may hold. History has a way of confounding those who define possibility in terms of what they can see and comprehend at a particular moment.

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The cover photograph, taken near Alert, Ellesmere Island, about 500 miles from the North Pole is by S. D. MacDonald for the National Museum of Canada.

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BEAUFORT SEA
Bering Strait
ALASKA
Fairbanks
Yukon River
Arctic Circle
YUKON TERRITORY
Dawson
Elsa
Keno Hill
Mayo
Pelly R.
Ross River
Kluane L.
Haines Junction
WHITEHORSE
Johnsons Crossing
Teslin
Atlin
Watson
Cassiar
Liard R.
Old Crow
Aklavik
Fort McPherson
Eagle Plain
Tuktoyaktuk
Reindeer Depot
Inuvik
Arctic Red River
Sachs Harbour
Banks Island
Holman Island
C. Parry
DISTRICT OF FRANKLIN
Victoria Island
Cambridge Bay
Coppermine
Fort Good Hope
Norman Wells
Fort Norman
Fort Franklin
Great Bear L.
NORTHWEST TERRITORIES
DISTRICT OF MACKENZIE
Mackenzie R.
Wrigley
Tungsten
Nahanni Butte
Fort Simpson
Lac la Martre
Rae
Snare Rapids
Snare Falls
Taurcanis
Yellowknife
Fort Providence
Jean Marie River
Hay River
Fort Liard
Great Slave L.
Fort Resolution
Pine Point
Snowdrift
Fort Reliance
Approximate Limit of Trees
Bathurst Inlet
Coppermine R.
Dubawnt R.
Mackenzie King I.
Prince Patrick I.
Mould Bay
Isachsen
Ellef Ringnes I.
QUEEN ELIZABETH ISLANDS
Cameron I.
Vanier
Alexander
Melville I.
Bathurst I.
Cornwallis I.
Resolute
North Magnetic Pole
Devon Island
Axel Heiberg I.
Eureka
Somerset I.
Prince of Wales I.
Spence Bay
Gjoa Haven
Pelly Bay
DISTRICT OF KEEWATIN
Baker Lake
Chesterfield Inlet
Rankin Inlet
Whale Cove
Eskimo Point
Churchill
FORT SMITH
Fifth Meridian
Hay R.
Slave R.
Uranium City
L. Athabasca
Peace R.
Grimshaw
Dawson Creek
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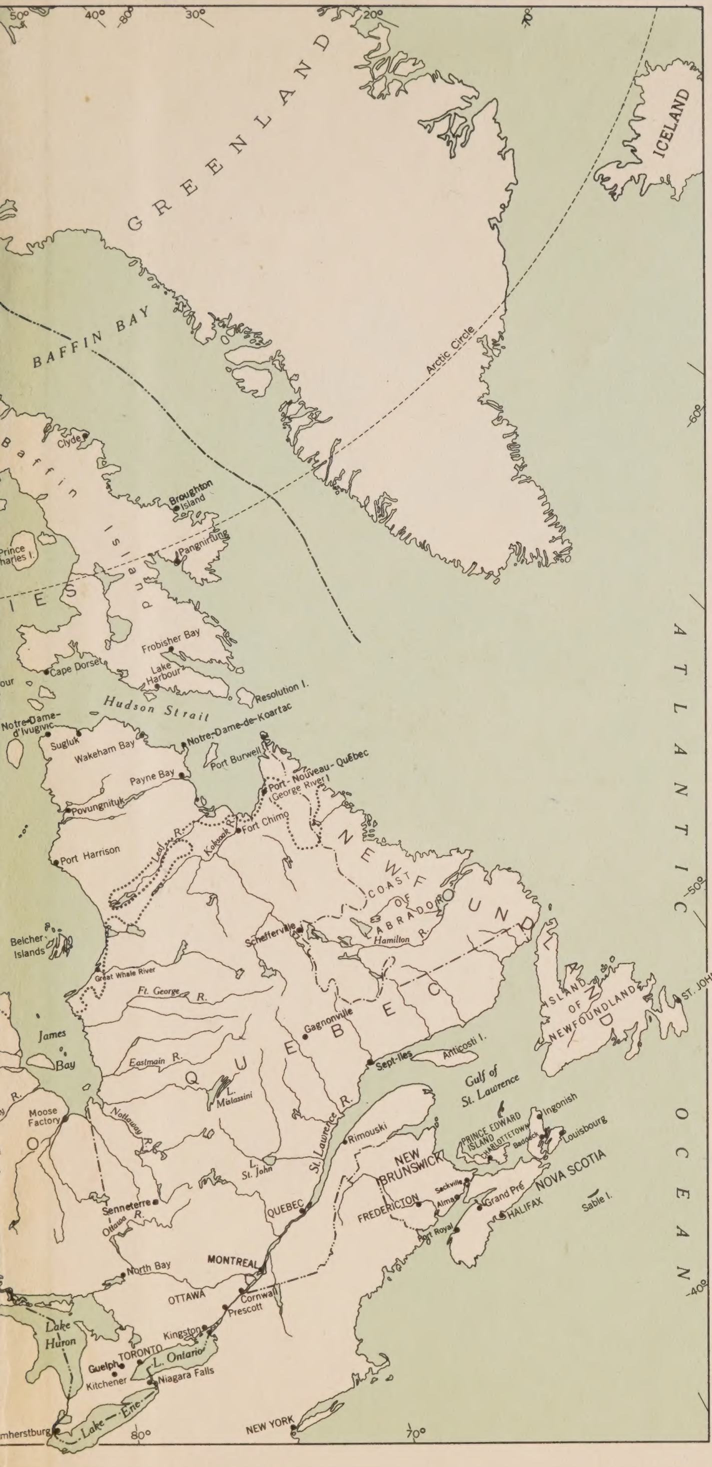
Queen Charlotte Islands
Prince George
Fraser R.
Jasper
EDMONTON
ALBERTA
SASKATCHEWAN
MANITOBA
Reindeer Lake
Lynn Lake
Churchill R.
Thompson
Nelson R.
Waskesiu L.
The Pas
Saskatchewan R.
Batoche
Battleford
Saskatoon
Lake Winnipeg
Revelstoke
Kamloops
Field
Banff
CALGARY
Cranbrook
Nelson
Vancouver Island
VANCOUVER
VICTORIA
PACIFIC OCEAN
Columbia R.
Shaunavon
REGINA
Wasagaming
Brandon
WINNIPEG
CANADA
UNITED STATES
Red R.
Keewatin
Fort Frances
L. Nipigon
ONT
Severn R.
Missouri River
Mississippi R.
Scale of Miles
100 0 100 200 300



Maps by
Water Resources Branch
Department of Northern
Affairs and National
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maps prepared by the
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